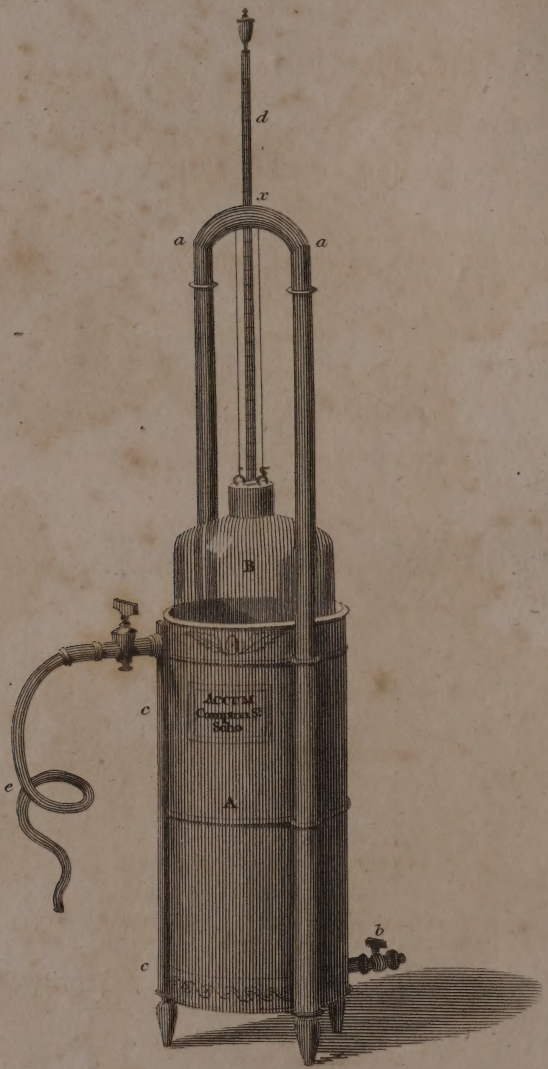
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A SYSTEM OF THEORETICAL AND PRACTICAL CHEMISTRY.

IN TWO VOLUMES, WITH PLATES.

BY

FREDRICK ACCUM,

TEACHER OF PRACTICAL CHEMISTRY, PHARMACY, AND MINERALOGY;

AND

CHEMICAL OPERATOR

IN THE ROYAL INSTITUTION OF GREAT BRITAIN.

VOLUME I.

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1803.

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CHEMICAL OPERATOR TO THAT CORPORATION,

DEDICATES,

BY THEIR PERMISSION,

AND

WITH THE HIGHEST RESPECT AND GRATITUDE,

THIS ATTEMPT,

TO PROMOTE THE GENERAL PURPOSES

OF

THEIR ESTABLISHMENT,

BY EXTENDING THE DIFFUSION

OF

SCIENCE.

PREFACE.

11, *Old Compton Street, Soho.*

THE following treatise has been composed for the instruction of such as are actually unacquainted with chemical science; and with that view I have followed such an arrangement of the subjects, as appeared best calculated to afford a clear and permanent knowledge of their relations and consequences.

As the proofs of chemistry are grounded upon an appeal to the senses, I have in the first place described some experiments, which are easy to be performed, and particularly adapted to exhibit the general nature of chemical action.

But mere facts do not constitute a science. The reasoning faculty must be exerted to dispose them in the order of cause and effect; first by the method called analysis, and afterwards in that of synthesis: which last may be considered as including those tentative processes of the mind called hypotheses, which in natural science are rendered legitimate by experiment.

To announce those generalities which have been deduced from the analytical labours of former philosophers, and constitute the theory of the science: to exhibit the conditions of the mutual actions of bodies; and to place the student upon an eminence whence he may contemplate the phenomena with advantage, and in many cases foretel events with certainty;...require a display of the nature of chemical attraction, or affinity, and of heat. I have distinctly stated the laws of affinity in the synthetical form, and have then proceeded to illustrate those laws, by a series of experiments sufficiently striking to interest the mind and fix the doctrine in the memory. The same method is adopted with regard to heat and light; which, together with attraction and repulsion, constitute the causes of every chemical change.

These positions and their illustrative proofs are immediately followed by the classification of the simple or undecompounded bodies, with their attributes, affections or habitudes; which latter are proved experimentally.

The gases and the theory of their formation are next considered; their characteristic properties are detailled; the processes for obtaining them described; and a variety of the most appropriate experiments explained, by applying the general doctrines to each particular fact. Among these important first lines of chemistry, the formation of water, the production of various acids; the nature of the air we breathe; eudiometry; combustion; and many phenomena of the utmost magnitude and value present themselves, and are elucidated by experiments.

The metals, alcalies, earths, &c. next succeed, and are treated in the same manner by direct reference to the facts they afford during chemical examination. The natural history of each, and their obvious physical and chemical properties are first stated; then follow the means of obtaining them; and lastly, their physico-chemical properties are shown, by a series of experiments. A similar method pervades the whole of the work.

I have endeavoured experimentally to unfold all the fundamental truths of the science. I have proceeded from first notions step by step; from generals to particulars; from premises to conclusions; deducing causes from their effects, and effects from their causes, in order to maintain a systematic connection between the several parts of the whole, and to recall to the memory, all the changes which bodies are susceptible of in their mutual actions.

I am persuaded this cannot be better done, than by determining their properties by experiments under different circumstances. Hence the same facts are exibited under various forms and relations, in order to oblige the mind to re-consider the same phenomena in different lights.

It is perhaps needless to state, that I have availed myself of all the authors who have cultivated and enriched this science. In many instances I found perspicuity of style and precision of detail, which I could not hope to make improvements; and in such cases I have not scrupled to transcribe whatever answered my purpose. But I have faithfully quoted my authorities, and rendered honor to whom honor is due.

They who are familiar with the science will nevertheless observe that I have done more than borrow from others. I have corrected errors which are found even in the works of modern authors of eminence; particularly in respect to the practical part of many processes. I have facilitated many operations; I have advanced a variety of new experiments, and pointed out such particulars in the performance of others as I have found in the course of my profession to be superior to those in general use.

The directions for performing chemical experiments, and the explanations in general, may be considered by some readers as too minute: but I am fully convinced that chemistry cannot be learned without actually applying to the operative part of the science. It is obvious that success must greatly depend on minute and clear instructions: this method of teaching cannot therefore be deemed trifling. I have indeed written for beginners: but accuracy and precision are so far from being faults, that they are more acceptable even to proficients, than that loose descriptive method which leaves the whole detail of quantities, order, and operation, to be supplied by the trials of the reader himself.

LONDON,
1803.

FREDRICK ACCUM.

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The Roman Figures denote the Volume, the Arabic show the pages.

ACHARD, I. 10
Adet, II. 102
Aikin, I. 10, II. 126
Babington, I. 10
Baldwin, I. 130
Beaumé, I.
Becher, I. 8
Beddoes, I. 10, 119
Bergman, I. 9, 59, 317, &c.
Bertholet, I. 10, 230, 317, &c. II. 347
Black, I. 9, 85, 234
Blagden, I. 10
Bond, I. 249
Bradley, I. 109
Brisson, I. 168
Buniva, II. 329
Burnet, I. 8
Biley, II. 341
Cabarris, I. 135
Cadet, I. 169
Carlisle, I. 140, II. 258
Cavendish, I. 10, 195, 226, 2 0
Chaptal, I. 10
Chenevix, I. 10, II. 28, 42, 142, 150, 264
Clayfield, II. 242, 245
Clement, I. 255
Clouet, I. 319, II. 122
Coates, I. 133
Coxwell, II. 309
Crell, I. 10, 133
Crichton, I. 10, 356, 368
Cruikshank, I. 10, 246, 254, &c. II. 333
Cuthbertson, II. 251, 259
Darcet, I. 169
Davy, I. 10, 62, 68, 103, 119, 124, 133, 231, 287, &c. II. 188, 245, 288
Desormes, I. 255
Dieman, I. 150, 247, II. 251
Dobbs, II. 272
Dundas, I. 10
Dundonald, I. 10
Ekeberg, II. 184, 204, 244
Englefield, I. 103, II. 183
Falconer, I. 226
Fiedler, II. 312
Fontana, I. 226, 283
Fordyce, I. 10
Fourcroy, I. 10, 317, II. 65 349

Gahn, II. 44
Garnett, I. 10
Gengembre, I. 270
Gilbert, I. 10
Giobert, I. 154
Gmelin, II. 14
Goetling, I. 10
Gren, I. 10, II. 201
Grange, La I. 10, II. 229
Guiton, I. 10, 170, 173
Hatchett, I. 10, II. 17, 18, 23, 24, 25 345, 346, 346, 349,
Helmont, I. 234
Henry, I. 10, 328 II. 323
Hermbstädt, I. 10
Herschell, I. 67, 101, 115, 220
Hecht, II. 27
Higgins, Dr. I. 156
— Prof. I. 10, II. 252
Hope, I. 10, II. 242
Howard, I. 10, II. 81
Hulme, I. 135
Humbolt, I. 10, 226, 228
Janetty, II. 179
Keir, II. 158
Kennedy, II. 228
Kirchhoff, II. 75
Kirwan, I. 10, II. 94
Klaproth, I. 10, II. 11, 14, 27, 29, 30, 68, 69, 114, 156, 208, 215, 228, 242
Kohl, II. 33
Ladriani, I. 86
Lair, I. 199
Lambert, I. 102
Landaff, I. 10
Laurenburgh, I. 249
Lavoisier, I. 9.
Leslie, I. 136
Lemery, I. 148
Lowitz, I. 10, 51, 86
Macgregor, II. 26
Macquer, I. 169
Magellan, I. 226, 240, II. 161
Margraff, I. 227
Marti, De I. 228
Marum, I. 132
Milner, I. 280
Monge, I. 319
Mons, I. 10
Nicholson, I. 10, 109, 252, II. 258
Nicola, I. 155
Nooth, I. 240
Pacts, I. 150, 249
Pallas, II. 116
Parker, I. 240
Pearson, I. 10, 208 II. 327, 330
Pelletier, I. 159, II. 98
Pepys, I. 51, 86
Pictet, I. 67, 102
Pontier, II. 20
Priestley, I. 9, 208, 225, 255, 278, 291, 309, 318
Proust, I. 10, II, 76, 128
Richter, I. 10
Rinman, II. 123
Roemer, I. 109
Rumford, I. 67, 80, 82, 124, 135
Rupert, II. 141
Rutherford, I. 139, 208
Sandman, II. 272
Saussure, I. 102, 170
Scheele, I. 102, 227, II. 272, 279, 318
Scherer, I. 10
Seguin, I. 10, 229
Stahl, I. 8
Stanhope, II. 248
Stodart, II. 121
Swanhard, I 347
Swediaur, I. 198
Tennant, I. 10, 171
Thenart, I. 362
Thompson, II. 288

Thomson, I. 10, 257
Tilloch, I. 10, 77
Tondi, II. 14
Tromsdorff, I. 10, 340, II. 214
Troostwyck, I. 150, 247, II. 257
Twiss, I. 96
Vauquelin, I. 10, 317, 318, II. 20, 21, 27, 122, 157, 204, 215, 216, 228, 298, 329 348, 349
Volta, I. 203
Walker, I. 51, 86
Watt, I. 93
Wedgwood, I. 10, 75, 122, 135, II. 20
Westrumb, I. 10, 133
Wiegleb, I. 10
Wollaston, I. 10, II, 257
Young, I. 103

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CONTENTS

OF

THE FIRST VOLUME.

PART I.

Page

SECT. I....DEFINITION OF CHEMISTRY..... 1

1. Method of performing chemical operations..

2. General nature of Chemistry..... 2

SECT. II....Subjects and importance of chemistry.....

SECT. III...View of the history of chemistry..... 5

PART II.

CORPUSCULAR THEORY,

AND

NATURE OF SIMPLE BODIES.

SECT. I....Corpuscular theory..... 11

SECT. II....Nature of simple bodies..... 13

SECT. III...Enumeration and classification of simple substances..... 14

PART III.

NATURE OF CHEMICAL ACTION.

Page

SECT. I....Instances of chemical action 17
Experiment I. II.
III. IV. 18
V. VI. 19
VII. 20

PART IV.

THEORY OF ATTRACTION.

Axiom of attraction 21
SECT. I....Proofs of the energy of attraction 22
Experiment I. II.
III. IV. 23
V. VI. 24
SECT. II...Division of attraction 26

PART V.

THEORY OF REPULSION.

Axiom of repulsion 27
SECT. I....Proofs of the energy of repulsion 28
Experiment I. II. III. 29
IV. V. 30
Inferences

PART VI.

THEORY OF CORPUSCULAR ATTRACTION.

Page
SECT. I....Instances of corpuscular attraction..... 33
Experiment I.....
Measurement of corpuscular attraction
SECT. II...General laws of corpuscular attraction 34
LAW I.
Experiment I. II.
LAW II. 35
LAW III. 36

PART VII.

NATURE OF CHEMICAL AFFINITY.

SECT. I....Theory of chemical affinity 37
SECT. II...Instances of chemical affinity..... 39
Experiment I.....
II. III. IV. 40
V. VI. VII..... 41
SECT. III....General laws of chemical affinity..... 43
SECT. IV....Experimental proofs of the laws of chemical affinity 45
LAW. I.
Proofs of law I.....
Experiment I. 46

Page
Law II. 46
Proofs of law II.....
Experiment I. II. III. 47
Law III. 48
Proofs of law III.....
Experiment I. II.....
III. IV. V. 49
Law IV. 50
Proofs of law IV.....
Experiment I. II. 51
Law V. 52
Proofs of law V.....
Law VI. 53
Proofs of law VI.....
Experiment I. II.
III. IV. V. VI. VII..... 54
VIII. IX..... 55
Law VII.
Proofs of law VII..... 56
Experiment I. II.....
III. IV..... 57
Law VIII. 58
Proofs of law VIII..... 59
Experiment I.....
Inferences..... 60

PART VIII.

HEAT, or CALORIC.

Sect. I....Theories of heat..... 62
Nature and theorems of heat 63
Sect. II...Methods of exciting and collecting heat..... 65
1. Production of heat by percussion
2. Production of heat by friction..... 66

Page
3. Production of heat by chemical action..... 67
4. Solar heat.....
5. Production of heat by the electric spark, and by galvanism..... 68
SECT. III...General effects of heat..... 69
Expansive property of heat.....
1. Expansion of fluid bodies by heat.....
Experiment I.....
2. Expansion of aeriform bodies by heat.....
Experiment I..... 70
3. Expansion of solid bodies by heat.....
Experiment I.....
Inferences..... 71
SECT. IV...Measurement of heat..... 73
1. Nature of the thermometer..... 74
2. Nature of the pyrometer..... 75
SECT. V....Exceptions to the expansion by heat..... 77
SECT. VI...Equal distribution of heat..... 78
SECT. VII..Propagation of heat, &c..... 79
Experiment I.....
SECT. VIII.Theory of caloric of fluidity..... 84
Experiment I..... 85
II..... 86
Production of artificial cold.....
Tables of freezing mixtures..... 87
SECT. IX...Conversion of solids and fluids into the aeriform or gazeous state 91
Conversion of solids into the gazeous state....
Experiment I.....
SECT. X....Conversions of fluids into the gazeous state... 92
Experiment I. II. III. IV..... 93
SECT. XI...Capacity of bodies for containing heat..... 98
Experiment I. II. III..... 99
SECT. XII..Radiation of caloric..... 101

PART IX.

LIGHT.

Page
SECT. I....Nature of light 106
1. Explanation of certain terms of light.....
2. Sources of light 107
SECT. II....Physical properties of light 108
1. Velocity of light.....
2. Momentum of light 109
3. Light moves in straight lines.....
Experiment I. 110
4. Reflection of light.....
Experiment I. 111
5. Inflection of light.....
Experiment I.
II. III. 112
6. Refraction of light.....
Experiment I. II. 113
SECT. III...Analysis of light by the prism 114
SECT. IV...Theory of colours 116
SECT. V....Chemical properties of light 118
1. Effects of light on vegetables.....
Experiment I. 120
2. Effects of light on animals 121
3. Effects of light on metallic oxids 122
Experiment I. II. III.
4. Effects of light on acids 126
Experiment I.
II.
SECT. VI...Combination of light with different bodies... 128
Solar phosphori.....
Photometer 135

PART X.

Page
SECT. I. OXIGEN 137
SECT. II. HIDROGEN 138
SECT. III. NITROGEN 139

PART XI.

SULPHUR.

SECT. I. Natural history of sulphur 140
Physical properties of sulphur 141
Method of obtaining sulphur 142
SECT. II. Experimental proofs of the properties of sulphur 144
Experiment I.
II. III. 145
IV. 146
Combination of sulphur with metals 147
Experiment I. II.
III. 149
Combination of sulphur with alcalies 150
Experiment I. II. 151
III. IV. 152
Combination of sulphur with earths
Experiment I.

PART XII.

PHOSPHORUS.

SECT. I. Natural history of phosphorus 153
Physical properties of phosphorus
Methods of obtaining phosphorus 154
Rationale of the processes

Page
Methods of purifying and moulding phosphorus 156
SECT. II...Experimental proofs of the properties of phosphorus 158
Experiment I.
II. III. 159
IV. V. 160
VI. 161
VII. 162
VIII. 163
IX. X. XI. 164

PART XIII.

DIAMOND,
OR
PURE CARBON.

SECT. I.....Natural history of diamond 166
Physical properties of diamond 167
SECT. II....Proofs of the combustibility of diamond 169

PART XIV.

NATURE
AND
FORMATION OF GASES.

SECT. I.....Nature of gases 175
Formation of gases 176
Experiment I, 177
Pneumatic apparatus 178
SECT. II....Methods of collecting gases, and transferring them from one vessel to another 180
Classification of gases 182

PART XV.

OXIGEN GAS.

Page
SECT. I.....Properties of oxigen gas..... 184
Methods of obtaining oxigen gas..... 185
Rationale of the processes.....
SECT. II....Experimental proofs of the properties of oxigen gas..... 188
Decomposition of oxigen gas by bodies destitute of metallic properties.....
Experiment I.....
II..... 189
III..... 190
Decomposition of oxigen gas by metallic substances..... 191
Experiment I.....
II..... 192
III. IV..... 193
Decomposition of oxigen gas by various other substances.....
Experiment I.....
II. III. IV. V. VI..... 194

PART XVI.

HIDROGEN GAS.

SECT. I.....Properties of hidrogen gas..... 195
Methods of obtaining hidrogen gas..... 196
Rationale of the processes.....
SECT. II....Experimental proofs of the properties of hidrogen gas..... 200
Experiment I. II.....

Page
Experiment III. IV. 201
V. VI. VII. 202
VIII. IX. X. 204
XI. 206

PART XVII.

NITROGEN GAS.

SECT. I. Properties of nitrogen gas 207
Methods of obtaining nitrogen gas 208
Rationale of the processes
SECT. II. Experimental proofs of the properties of nitrogen gas 210
Experiment I. II. III.
IV. V. 211
VI. 212

PART XVIII.

ATMOSPHERIC AIR.

SECT. I. Mechanical examination of atmospheric air ... 214
Experiment I.
II. III. 215
IV. V. VI. VII. VIII. IX. ... 216
X. XI. XII. XIII. 217
SECT. II. Chemical examination of atmospheric air 212
Analysis of atmospheric air 222
Experiment I. II.
III. 224
SECT. III. ...Eudiometry 225
Priestley's eudiometer
Scheele's ditto 227
De Marti's ditto 228

Page
Humbolt's eudiometer 228
Seguin's ditto..... 229
Bertholet's ditto..... 230
Davy's ditto..... 231
General remarks..... 232

PART XIX.

CARBONIC ACID GAS.

SECT. I.....Properties of carbonic acid gas..... 234
Methods of obtaining carbonic acid gas 235
Rationale of the processes.....
SECT. II....Experimental proofs of the properties of carbonic acid gas 238
Experiment I. II.....
III. IV..... 239
V..... 240
VI. VII. VIII..... 241
IX..... 242

PART XX.

LIGHT CARBONATED HIDROGEN GAS.

SECT. I...Properties of light carbonated hidrogen gas.... 243
Methods of obtaining light carbonated hidrogen gas 244
Rationale of the processes.....
SECT. II...Experimental proofs of the properties of light carbonated hidrogen gas 246
Experiment I. II. III.
IV..... 247

PART XXI.

HEAVY CARBONATED HIDROGEN GAS.

Page

SECT. I.....Properties of heavy carbonated hidrogen gas..
Methods of obtaining heavy carbonated hidrogen gas..... 249
Rationale of the processes..... 250
SECT. II.....Experimental proofs of the properties of heavy carbonated hidrogen gas..... 253
Experiment I..... 254
II.....

PART XXII.

GAZEOUS OXID OF CARBON.

SECT. I....Properties of gazeous oxid of carbon..... 256
Methods of obtaining gazeous oxid of carbon.. 257
Rationale of the processes.....
Inferences..... 259

PART XXIII.

SULPHURATED HIDROGEN GAS.

SECT. I.....Properties of sulphurated hidrogen gas..... 261
Methods of obtaining sulphurated hidrogen gas 262
Rationale of the processes.....
SECT. II....Experimental proofs of the properties of sulphurated hidrogen gas..... 265
Experiment I. II.....

Page
Experiment III. IV. 266
V. VI. 267
VII. VIII. 268
IX. X. 269

PART XXIV.

PHOSPHORATED HIDROGEN GAS.

SECT. I. Properties of phosphorated hidrogen gas 270
Methods of obtaining phosphorated hidrogen gas 271
Rationale of the processes.....
SECT. II. Experimental proofs of the properties of phosphorated hidrogen gas 273
Experiment I.
II. 274
III. IV. 275
V. VI. 276
VII. 277

PART XXV.

NITROUS GAS.

SECT. I. Properties of nitrous gas 278
Methods of obtaining nitrous gas 279
Rationale of the processes.....
SECT. II. Experimental proofs of the properties of nitrous gas 282
Experiment I.
II. III. 283
IV. V. 284
VI. VII. VIII. 285
IX. X. 286

Page
Experiment XI. 287
XII. 288
XIII. 289

PART XXVI.

GAZEOUS OXID OF NITROGEN.

SECT. I.....Properties of gazeous oxid of nitrogen..... 292
Methods of obtaining gazeous oxid of nitrogen 294
Rationale of the processes.....
SECT. II....Experimental proofs of the properties of gazeous oxid of nitrogen 300
Experiment I.
II. III. IV. 301
V. VI. 302
VII. VIII. IX. 303
X. 304
XI. XII. XIII. 306
XIV. 307
Inferences

PART XXVII.

AMMONIA.

SECT. I.....Properties of ammonia 309
Methods of obtaining ammonia..... 310
Rationale of the processes.....
SECT. II....Experimental proofs of the properties of ammonia..... 312
Experiment I. II.....
III. IV. V. 313
VI. VII. 314
VIII. IX. 315
X. 316

PART XXVIII.

SULPHUREOUS ACID GAS.

Page
Sect. I.....Properties of sulphureous acid gas 318
Methods of obtaining sulphureous acid gas... 319
Rationale of the processes.....
Sect. II....Experimental proofs of the properties of sulphureous acid gas 321
Experiment I. II.
III. IV..... 322
V. VI. 323
VII. 324
VIII. IX. 325
X. 326

PART XXIX.

MURIATIC ACID GAS.

Sect. I.....Properties of muriatic acid gas..... 327
Methods of obtaining muriatic acid gas 328
Rationale of the processes.....
Sect. II....Experimental proofs of the properties of muriatic acid gas..... 330
Experiment I.
II. III..... 331
IV. V. 332

PART XXX.

OXIGENATED MURIATIC ACID GAS.

Sect. I...Properties of oxigenated muriatic acid gas..... 333
Methods of obtaining oxigenated muriatic acid gas 334
Rationale of the processes.....
Sect. II...Experimental proofs of the properties of oxigenated muriatic acid gas 336

Page
Experiment I. II. 336
III. IV. 337
V. VI. 338
VII. VIII. 339
IX. X. 340
XI. XII. XIII. 341
XIV. 342

PART XXXI.

FLUORIC ACID GAS.

Sect. I. Properties of fluoric acid gas 343
Methods of obtaining fluoric acid gas 344
Rationale of the processes
Sect. II. Experimental proofs of the properties of fluoric acid gas 345
Experiment 1. II.
III. IV. 346
V. 347

Phosphorated carbonated hidrogen gas 348

PART XXXII.

THEORIES OF COMBUSTION.

Sect. I. Lavoisier's theory of combustion 350
Sect. II. Thomson's theory of combustion 357

A

SYSTEM

OF

THEORETICAL AND PRACTICAL

CHEMISTRY.

PART I.

SECT. I.

DEFINITION OF CHEMISTRY.

CHEMISTRY is that department of physical science the object of which is to investigate and account for the changes produced in all bodies in nature, by the mutual action of their parts upon each other, by means of which their physical properties are altered, and their individuality destroyed.

1. METHOD OF PERFORMING CHEMICAL OPERATIONS.

The method which chemistry employs to favor the action of bodies upon each other consists in the proper application of those substances to each other, which experience has taught us

are best calculated to produce certain changes, that, in many cases, would otherwise be too minute to affect the senses individually.

Those operations themselves are called CHEMICAL PROCESSES, or EXPERIMENTS.

2. GENERAL NATURE OF CHEMISTRY.

Chemistry therefore consists in a detail of those facts which are founded on *experiments* and *observations*. Its basis is EXPERIENCE; from this, by regular conclusions, it deduces a THEORY, and connects a series of accurately established facts into a certain order, called a SYSTEM.

It follows from this that the evidence of chemical truth is, strictly speaking, only probable, but not absolutely certain. This probability however is so much the greater, as the experiments on which the observations are founded are more numerous, and have been more accurately performed. All possible exceptions then being made, we may venture to consider the results which offer themselves as true, till other facts are furnished, which in a more satisfactory manner prove their fallacy.

It has been thus, by simple experiments and observation, that the science has been enriched with a store of facts. These facts have been gradually connected together, and arranged in such order as appeared most proper for exhibiting their reciprocal relation to each other; and, (at the same time) for referring them to a smaller number of general heads, in order to consult them with the least difficulty, and to trace the *laws* that regulate them.

SECT. II.

SUBJECTS AND IMPORTANCE OF CHEMISTRY.

ALL material bodies are the subjects of chemical research. The solid matters composing the terrestrial mass of the globe we inhabit; the aqueous fluids which penetrate its cavities, or float about its surface; the more subtle gazeous matter circumfused around it; the agencies of heat, light, and other imponderable substances expanded through space, are subjects for the chemical philosopher.

The events which chemistry holds out are equal to, and perhaps more important than those which belong to mechanical philosophy. It extends itself into the province of active life. It is the nursing mother and guide of innumerable important arts. The arts of dying, bleaching, tanning, glass-making, printing, the working of metals, &c. are purely chemical. *Agriculture* can only be rationally improved by calling in the assistance of the chemical philosopher; for it is chemistry which explains the phenomena of vegetation, germination, the growth, the ripening, and the death of plants.

The GARDENER, whose employments are more curious than those of the farmer, equally needs its assistance. The nature of the different manures necessary for the various kinds of vegetables, the influence of light, the different temperatures, the quantity of moisture, the preservation of seeds, roots, plants, &c. are all founded upon chemical principles.

Chemistry likewise directs the labours of the HUSBANDMAN and the RURAL-ECONOMIST. In the DAIRY milk cannot be kept

sweet and fresh, butter cannot be made, cheese cannot be prepared, without a skill founded wholly upon chemical principles.

The CULINARY ART, for preparing wholesome and nutritious food; and the method of preserving bacon, hams, and other animal and vegetable substances, is entirely chemical.

The whole PROCESS OF THE VINTAGE, the art of the brewer and distiller, the preparation of cyder, perry, and home-made wines, all depend upon chemical principles.

In MEDICINE and PHARMACY great benefits have been derived from the discoveries of chemical philosophers.

The chemist begins his enquiries where those of the natural historian and those of the natural philosopher terminate. The first of these examines bodies, in order to arrange them into certain classes, genera, and species: the second investigates the general properties of objects, such as their density, elasticity, figure, &c. and calculates the relative forces of their mechanical actions.

The chemist however goes further;...he looks into the more intimate structure of substances; he separates their heterogeneous particles from each other; he resolves them further into their simple or elementary substances, and examines their nature and properties when in a detached or simple state. He thus learns their reciprocal relation to each other, and becomes enabled to re-combine them in proportions different from those in which they were united by nature, in order to form new and useful compounds, which nature herself does not produce.

But chemistry is not only valuable as an art which supplies many of our wants, our comforts, and luxuries; its objects are sublime and beautiful in another point of view...it removes the veil from the fabric of nature, and makes us acquainted with all the phenomena which happen around us...it affords pleasure to the senses, and calls into action a laudable curiosity, which characterizes the minds of those who are of a scientific turn, exciting at the same time a spirit of rational enquiry, which is capable of producing the most beautiful and striking phenomena, well calculated to serve as an instructive and rational amusement.

SECT. III.

VIEW
OF
THE HISTORY OF CHEMISTRY.

FROM what has been already stated, it becomes obvious that chemistry may be considered both as a science and as an art:... As a science, it may be said to be of modern date; but as an art, it must be coeval with the earliest exercise of the industry of man; for many operations now considered chemical, certainly must owe their invention to the immediate wants of society. The method of kindling fires, the arts of baking bread, moulding clays, and burning them into pottery; extracting metals from their ores, the methods of working them, and various other processes, were certainly known to the ANTEDILUVIANS. If we attempt to trace its birth, as a science, we find it originating in fables and obscurity; nor indeed could we derive any chemical advantage, if it were possible to dispel the cloud by which it is enveloped.

Whether Tubal-Cain who is stated to have been a worker in metals, whether Noah who made wine, and who preserved the requisite stores of provisions in the ark, during the deluge, whether Moses who burnt the golden calf of the Israelites, or whether Cleopatra who is said to have dissolved a pearl, understood chemistry, are questions important perhaps to the antiquarian, but of little value to the chemist. It is more plausible to suppose that a science so much depending on the state of the arts, the civilization of man, and the experience of ages, could not possibly exist in such a remote time. But, as it would be in some respect unpardonable for those who devote themselves to

the study of chemistry, to be utterly unacquainted with its history, we shall shortly notice the outlines of this history and fix the dates of the progressive discoveries of our predecessors which led to the establishment of the science.

The PHŒNICIANS were the first who applied themselves to the examination of the effect of different bodies upon each other, which may be called chemical. They invented the art of tinging garments with a purple-coloured matter, produced by a species of shell-fish. They were likewise the inventors of making glass, artificial gems, perfumes, and odoriferous balsams. They also invented the art of preserving the fruits of various plants and vegetables.

The CARTHAGINIANS, who were a colony of the Phœnicians, learnt their arts; but the priests in whose hands the learning was retained, handed them to their successors veiled in hieroglyphic mystery.

The GRECIANS derived their arts depending upon chemical principles from the Phœnicians. They practised all the inventions of their predecessors successfully.

It is natural that the obvious difference or changes of the bodies that surround us could not escape the notice of a people of so philosophical a turn of mind as the Grecians; hence both Aristotle and Empedocles taught the doctrine of the four supposed elements, air, earth, fire, and water.

The ROMANS, who were not distinguished among the nations of the ancient world as discoverers in the arts, or inventors in science, after having conquered and subjugated almost all the civilized parts of the earth, arduously cultivated the arts of their masters, the Grecians. They understood the art of making excellent wines and ardent spirit. They knew the application of manures. They prepared incombustible cloth for wrapping up the dead bodies which were destined to be burnt, in order to preserve their ashes distinct from those of the funeral pile. They moulded clays, and converted them, by burning, into different kinds of pottery; they were also acquainted with almost all

the metals, and the methods of coining them. They were skilled in the culinary art. Their cooks invented delicious sauces, as luxuries for their table. And the remains of their aqueducts, and other works of architecture, evince the incomparable perfection of their cements.

But all the arts, the sciences, and literature of the Romans and Greeks were destined to sink into oblivion. Hosts of barbarian conquerors descended upon them from the North, the energies of civilization withered at their touch, and its works were destroyed before them.

Driven from Europe, the arts obtained an asylum with the ARABIANS, who improved many, and applied them to medicine. The attachment of this nation to magic, and their inclination for the marvellous, soon increased the mysteries in which the arts were then already involved; and hence alchemy, or the art of transmuting base metals into gold, took its rise. This happened about the commencement of the fourth century.

As this delusive dream of the imagination held out a bait to avarice, it soon acquired a train of followers. Intoxicated with the idea of the boundless wealth that would reward success, the great object was the philosopher's stone, and the possibility of the discovery of an universal medicine, which should cure every disease, and give immortal health and life to embodied man. The research was pursued with an ardour which no disappointment could damp, and the *mania* spread from one country to another. In Egypt it attracted the attention of the government. Dioclesian, apprehensive that the dreams of the alchemists might be realized, ordered all their books to be burnt, in order that he might subdue them with more facility.

After this period the alchemists were strongly opposed by several able and learned men. They were considered as people who held intercourse with malevolent spirits. Roger Bacon, the alchemist, who is supposed to be the inventor of gun-powder, was excommunicated by the Pope and imprisoned ten years, for supposed dealings with the Devil; and Paracelsus was thought to

have an evil spirit confined in the pommel of his sword. Indeed, many of the adherents of alchemy endeavoured to enforce the belief of charms and spells; Paracelsus, the most impetuous man, who, in ostentation and lies surpassed all his predecessor alchemists, promised immortality in this world to his followers, but his premature death, which happened in 1541, exposed his vanity, and blasted all their hopes.

It would surpass our limits, were we to give a circumstantial detail of the state of the chemical arts at that period. It will be readily conjectured, that owing to the great numbers of experiments which were performed amongst the alchemists, many valuable discoveries must have been made unintentionally. The alchemists actually collected a rich store of important chemical facts, and if they did not succeed in drawing gold from their furnaces, they produced those materials on which the true science of chemistry was afterwards erected: *for as yet the science of chemistry did not exist.*

At the end of the seventeenth century chemistry began to assume a scientific form. The scattered chemical facts which the alchemist had discovered were collected, arranged, and reduced to principles.

The first chemical writer that excites our notice is Becher. This man collected all the facts which were noticed before him, and pointed out many important objects to which the researches of chemists ought to be directed. The publication of his *Physica Subterranea,* in 1669, forms a very important æra in the history of chemistry. At that period chemistry escaped for ever from the trammels of alchemy, and became the rudiments of the science which we find at present. Becher distinguished himself so highly by his chemical knowledge as to cause the names of all former theorists to be forgotten, after having laid the foundation to the famous system of phlogiston. He died in the year 1682.

Soon after his death arose one of his pupils, whose name was Stahl. He simplified and improved the doctrine of his master so much that he made it entirely his own; and accordingly it

has been known ever since by the name of the *Stahlean Theory*. He was the first who had a clear notion of chemical union, and gives many instances of double elective attractions. His writings have done him immortal honour, and ranked him amongst the first characters of the age in which he lived. He died in the year 1704.

Ever since the death of these chemists, chemistry has been cultivated with success. Men of eminence have appeared every where, discoveries have been multiplied which led to numerous important facts. The names of Margraaf, Scheele, Bergman, Baume, Rouelle, &c. will remain distinguished in the annals of chemical science.

The spirit of chemical enquiry which these philosophers had infused summoned on a sudden into action the faculties of the most learned men of Europe. Several of the invisible agents which form so important a part in the œconomy of nature were discovered. Dr. Priestley discovered in 1777, various aerial fluids, formerly totally unknown to chemists; Dr. Black traced the laws of latent heat, and discovered the carbonic acid. The science of electricity was (as it were) created, the thunder was taken from the clouds, and the properties of the atmosphere were examined with accuracy.

All these new discoveries embarrassed the votaries of the doctrine of Stahl; and the conclusions to which they led, were of such a nature as to puzzle and to contradict many of the laws of the science. It was requisite to take but one step further that the doctrine of phlogiston might be exploded for ever. This was left to Lavoisier.

Lavoisier, endowed by nature with the most happy genius for science, and favoured by his own princely fortune, and the liberal bounty of the French government, instituted a series of ingenious and accurate experiments, the result of which proved to demonstration that the theory of phlogiston was founded in error. His experiments were repeated under every diversity of circumstances by all the philosophers of Europe: his reasonings

and inferences were vigorously attacked by the defenders of the phlogistic theory; a kind of chemical war was thus kindled in the republic of letters, which was carried on with great animosity; and posterity will see with regret, men of undoubted genius at times divesting themselves of the armour of truth and candour, and endeavouring to serve their party, and stab their adverse fellow-labourers with darts steeped in the poison of calumny and falsehood. These things have passed away; the contest has been productive of good effects which infinitely surpass the bad ones; it has occasioned an accumulation of facts; produced a rigid examination of theories and opinions; introduced accuracy in chemical experiments, and given that tone and vigour to the cultivators of chemistry which have brought to light the most sublime and unlooked-for truths.

The principles of Lavoisier have triumphed, and are now taught in all the schools of Europe; his opponents have become his disciples; and thus he has erected the luminous and beautiful theory of chemistry which all the chemists of Europe, Priestley excepted, have now adopted. What a pity that the sanguinary tyranny of Robespierre should not even have spared this man, who perished on the 7th of May, 1794, under the axe of the guillotine.

Amongst the number of philosophers, who have since that time cultivated and enriched the new theory of chemistry, with discoveries which will for ever give immortality to their names, we have to notice Aikin, Babington, Bancroft, Beddoes, Blagden, Cavendish, Chenevix, Crichton, Cruickshank, Davy, Lord Dundonald, Lord Dundas, Fordyce, Garnett, Hatchett, Henry, Higgins, Hope, Howard, Kirwan, Bishop of Landaff, Murray, Nicholson, Pearson, Tenant, Tilloch, Thomson, Wedgwood, and Wollaston; Achard, Crell, Gilbert, Gren, Goetling, Humbold, Hermbstaedt, Klaproth, Lowitz, Richter, Scherer, Tromsdorf, Westrumb, Wiegleb, Bertholet, Chaptal, Fourcroy, Lagrange, Guiton, Van Mons, Proust, Sequin, Vauquelin, &c. &c.

ON THE

CORPUSCULAR THEORY;

AND ON THE

NATURE OF SIMPLE BODIES.

PART II.

SECT. I.

CORPUSCULAR THEORY.

WHEN we contemplate the objects around us, and confine our views to the globe we inhabit, we discover a vast variety of substances which may well excite our curiosity and arrest our attention. We perceive our earth to be a solid globe, composed of an assemblage of substances considerably fixed, and not to be destroyed without a considerable force of impulse. We observe a large part of it covered with an ocean, and numberless streams of cold liquid matter tending with great activity to incessant motion.

Around this earth and water, to a great but unknown height, is circumfused an atmosphere of an impalpable gazeous fluid, intermingled with portions of every solid or aqueous matter that by an extreme comminution is capable of suspension in this aerial fluid.

Different opinions have been formed concerning the question, in what manner this globe was brought into the present distribution of its parts.

Divines have endeavoured to justify the account of Moses, by an appeal to the present laws of nature. But Burnet and others have been easily convicted of supposing primæval states of things utterly incompatible with these laws.

Chemists have conceived that the origin of the earth, in its present form, is from a general liquidity of its whole matter: others again have attributed it to the action of fire.

Astronomers have been persuaded that it was owing to the action of some comet, or to an altered arrangement of the planets.

But none of these hypotheses are sufficiently consistent with the known laws of nature. We have no *data* to reason from except the agencies of the present physical laws; if we venture hypotheses incompatible with them, or if we attempt to conjecture what was prior to them, we of course reason unphilosophically. We shall therefore dismiss this question, and consider the matters which constitute this earth as they actually appear before us.

When we examine these substances with a mere superficial eye, we are led to conclude that they are composed of minute parts. If we examine the particles of many of those bodies which appear homogeneous, we discover that they consist of various distinct substances, whose properties are often widely different from those of the whole, of which they form a part.

Philosophers have from this inferred, that all bodies in nature consist of certain moleculæ or particles which never touch each other in any state hitherto known. When these particles are dissimilar, the body which they form is called a *compound*, or heterogeneous body; but when the particles are similar, they then form what is denominated a *simple*, or homogeneous body.

If, for instance, we take glass, which is a compound body, consisting of silex and potash, and reduce it to powder, each particle of glass, however fine, consists of a particle of silex and a particle of potash, bodies which are dissimilar to each other. But if we take a piece of sulphur, or a metal, and reduce it to powder, the particles which offer themselves are all alike; for the sulphur, or the metal, is a simple body.

SECT. II.

NATURE OF SIMPLE BODIES.

SIMPLE bodies consist of particles which cannot be further separated into others of a more simple nature, or reproduced by artificial means. The true character of them is immutability of properties, unity, and similarity.

It does not follow from this that these bodies are absolutely simple; on the contrary, it is very possible that they are compound. It cannot be doubted that, as the science advances towards perfection, many of them will be found so. Very probably a new set of simple bodies will offer itself, of which we are at present ignorant. These again may perhaps be decomposed, till at last, when the science has reached the highest degree of perfection, those really elementary substances will come into view, of which all bodies are ultimately composed. Whenever this shall happen the list of simple substances will probably be reduced to a much smaller number than at present; till this however does take place we are entitled to consider them as simple substances, according to the present state of our knowledge.

Their number amounts now to forty-five.

They may be conveniently arranged in the following order

SECT. III.

ENUMERATION AND CLASSIFICATION.

OF

SIMPLE SUBSTANCES.

DIVISION I.

SIMPLE SUBSTANCES PRODUCIBLE BY ART.

2 IMPONDERABLE SUBSTANCES.

Light
Caloric.

PONDERABLE SUBSTANCES.

3 *Combustible bodies destitute of metallic properties.*

Sulphur
Phosphorus
Diamond.

22 *Combustible bodies, possessing metallic properties, called*

METALS.

Arsenic	Antimony
Tungsten	Tellurium
Molybdena	Mercury
Chrome	Zinc
Columbium	Tin
Titanium	Lead
Uranium	Iron
Cobalt	Copper
Nickel	Silver
Manganese	Gold
Bismuth	Platina

INCOMBUSTIBLE BODIES.

7 EARTHS.

Silex
Alumine
Glucine
Zircon
Agustine
Yttria
Magnesia.

5 ALCALIS.

Barytes
Potash
Soda
Strontia
Lime

DIVISION II.

6 SUBSTANCES NOT YET PRODUCIBLE BY ART, BUT ANALOGICALLY CONSIDERED AS SIMPLE.

Oxigen
Nitrogen
Hidrogen
Muriatic radical
Fluoric radical
Boracic radical.

Such are the bodies which the corpuscular theory considers as simple, and to which chemical writers have given the appellation of RADICALS. Some can only be exhibited to our view in their simple state, others on the contrary have not yet been successfully exhibited experimentally, uninsulated. Their existence can nevertheless be inferred from the analogy of certain general and well established facts.

ON

THE NATURE

OF

CHEMICAL ACTION.

PART III.

THE different actions which result from the proper application of the bodies enumerated before, when either in a simple state, or when combined together, are founded on certain agencies inherent in all matter. This we take for granted and consider as a fact, without pretending to explain *how* bodies came to be possessed of these agencies, or how they are capable of exerting it.

Philosophers therefore express the unknown causes which produce the changes by the metaphors of ATTRACTION and REPULSION.

Before we attempt to give an explanation of these terms, we shall endeavour to exemplify what is understood by chemical action in general. We therefore flatter ourselves that the following simple facts intended for that purpose, will not be deemed frivolous, our chief object being to advance in this place some palpable, positive, and negative proofs which show, that whenever chemical action takes place, the properties of bodies become altered, and their individuality destroyed.

SECT. I.

INSTANCES OF CHEMICAL ACTION.

EXPERIMENT I.

LET a small portion of marble, or chalk, reduced to powder, be diffused in a quantity of water, the marble presented to the water will fall to the bottom of the vessel and remain unaltered. On shaking up the whole, a white turbid mixture will be formed, but on letting it stand undisturbed, the marble will again fall to the bottom and the supernatant fluid remain transparent, and unaltered.

In this case no chemical action has taken place, for neither the properties of the marble or the water are altered if examined chemically.

EXPERIMENT II.

If we let fall a like quantity of marble or chalk into another fluid, called an acid; for instance, into vinegar, or nitric, muriatic, or sulphuric acid, the effect then will be different. A violent action will take place the instant they come into contact, the marble will gradually disappear in these fluids, and become more or less dissolved, and a transparent solution will be obtained.

In this case a chemical action has taken place between the bodies brought into the sphere of action, for the properties of both the substances can no longer be distinguished, their appearances are more or less altered, and their individuality destroyed.

Experiment III.

It is a well known fact, that if oil and water are added to each other they will not mix, because no sensible chemical action takes place between them under such circumstances; but if we add to the oil and water a sufficient quantity of another substance, called an alcali, for instance, potash or soda, the oil, the water, and the alcali will then unite and form a saponaceous compound, which has a milky appearance, and renders water opaque.

A chemical action has then taken place between them, for the properties of the oil, the water, and the potash are lost; and a compound possessing new properties has been formed.

Experiment IV.

If we put into a phial equal quantities of oil of turpentine, highly rectified alcohol, and a concentrated solution of carbonate of potash, and shake them together, no chemical change takes place, the different fluids will apparently mix, but on suffering them to stand undisturbed, they will separate again and arrange themselves into distinct spherules. The heaviest fluid will sink with the greatest celerity, and they will place themselves over each other according to their specific gravities. *Three different fluids will thus be contained in one phial, which do not mix but constantly remain separate.* In this instance therefore no chemical action takes place between the bodies presented to each other.

But if we bring the same substances into contact with others, of a different nature, the case will be different, for violent chemical actions will ensue under favorable circumstances, for instance,

Experiment V.

Accension of oil of turpentine, by the affusion of nitrous acid.

If we put into a tea-cup about one table-spoonful of oil of turpentine, and add to it double that quantity of very concentrated nitrous acid, a violent action takes place, and fire and flame will be produced.

Remark...As it is our duty to point out such experiments as may prove unsafe to those who never applied their hands to the practical part of chemistry, we must remark that in performing this experiment care should be taken to avoid dangerous events; for the cup is sometimes shattered to pieces, and the mixture is thrown about in all directions to a considerable distance; it is therefore necessary to fasten the vessel containing the nitrous acid to the end of a long stick, in order that the operator may be at a distance when the accension takes place, which happens the instant the acid comes into contact with the oil.

Experiment VI.

Production of heat, (sufficient to make water boil,) by the mere mixture of sulphuric acid and alcohol, or water.

If half an ale-glass full of sulphuric acid of commerce be hastily mingled with half that quantity of alcohol or water, the mixture instantly becomes so hot as to render the glass insupportable to the hands. A small quantity of water contained in a thin glass tube may be made to boil when immersed in it for a few minutes only.

Remark....Great caution is likewise necessary in making this experiment, lest the glass should crack from the sudden heat, and throw the mixture about to the manifest danger of the ope-

rator. The safest method is to mix the two fluids gradually; by this means the heat is produced slowly; whereas if both fluids are at once mingled together the heat is almost instantaneous, and rises considerably above that of boiling water.

Experiment VII.

Production of Sulphate of Potash.

If a concentrated solution, carbonate of potash, be mingled with sulphuric acid, the two fluids unite, a very brisk effervescence takes place, and a solid mass of salt (sulphate of potash) will be produced.

These experiments, which shall be more fully considered hereafter, are merely advanced to prove that the individuality of different substances becomes destroyed, that is to say, that a chemical action takes place when they are presented to each other, under such circumstances as experience has taught us are necessary to produce such effects. The conditions, or artificial arrangements requisite for that purpose, resolve themselves into the general operations of chemistry; these shall be circumstantially exhibited hereafter.

THEORY

OF

ATTRACTION.

PART IV.

THE terms attraction and repulsion, in the language of modern philosophers, are employed merely as the expression of the general facts, that the masses or particles of matter have a tendency to approach to, or to recede from one another, and to unite to, or repel each other, under certain circumstances. Hence the following

AXIOM OF ATTRACTION.

All bodies whatever have a tendency or power to attract each other more or less; they search as it were, and make efforts, when left to themselves, to approach one another in order to unite, or to come into apparent contact. This energy is called the POWER OF ATTRACTION.

This attraction is mutual; it extends to indefinite distances. All bodies whatever, as well as their component elementary particles are endued with it. It is not annihilated at how great a distance soever we suppose them to be placed from each other; neither does it disappear though they be arranged ever so near each other.

The nature of this reciprocal attraction, or at least the cause which produces it, is altogether unknown to us. Whether it be inherent in all matter, or whether it be the consequence of some other agent, are questions beyond the reach of human understanding; but its existence is nevertheless certain.

SECT. I.

PROOFS
OF
THE ENERGY OF ATTRACTION.

THAT the power of attraction really exists is obvious from the slightest view of the phenomena of nature. It is proved with mathematical certainty that the celestial bodies, which constitute the solar system, are urged towards each other by a force which preserves them in their orbits. It is further proved beyond any doubt that this planetary attraction is possessd not only by the heavenly bodies as wholes, but that it also extends to the smaller particles of which they are formed, as may be evinced by means of the following experiments:

Experiment I.

If we place two or more globules of mercury on a dry glass or earthen plate, and push them gently towards each other, the globules will attract each other, and form one mass or sphere greater in bulk but precisely the same in nature.

Experiment II.

If a plate of clean glass, perfectly dry, be laid on a large globule of mercury, the globule notwithstanding the pressure applied to it continues to preserve its spherical form; if we gradually charge the plate with weights carefully, the globule will be depressed and become thinner and thinner; but if we again remove the weights from the plate, the mercury will instantly recover its globular figure and push up the glass before it.

In both these experiments we see that there exists an attraction between the particles of mercury; in the first, the globules which are in contact with the plate of glass leave this substance completely, they attract each other and form a sphere greater in bulk. A mere inert fluid would in any case retain the figure it once possessed. It could not be endued with a globular form unless a real reciprocal attraction among its particles took place, which in the latter experiment is still more striking, for it there is not only superior to gravitation, but actually overcomes an external force.

Experiment III.

If a glass tube of a fine bore be immersed in water, contained in any vessel, the fluid will ascend to a certain height within the tube above its level, and its elevation in several tubes of different sizes will be reciprocally as the diameter of their bores.

This kind of attraction which takes place as well *in vacuo* as in the open air, has been called capillary attraction. It is this attraction which causes water to rise in sponge, cloth, sugar, sand, &c. for all these substances may be considered as fine tubes in which the fluid ascends.

Remark....The ascension of fluids in glass tubes of a fine bore succeeds best when the inside of the tube has been previously moistened, which may conveniently be done by blowing through it with the mouth. And if the water be coloured with a little red or black ink its ascension will be more obvious, particularly if the tube be held against a sheet of white paper.

Experiment IV.

If two plates of glass, previously wetted be made to meet on one side, and be kept open at the other, at a small distance, by the interposition of a shilling, or any other thin substance, and then immersed in water, the fluid will ascend between the two

plates unequally. Its upper surface will form a curve, in which the heights of the several points above the surface of the fluid will be to one another reciprocally, as their perpendicular distance from the line in which the plates meet. The ratio of this attraction is therefore as the squares of the increments with which the plates open.

Here then we have two other instances that an attraction prevails among the particles of bodies. For in both cases part of the fluid has left the contiguous mass, contrary to the laws of gravitation. It is drawn up as it were, or attracted by the tube, or plate of glass.

Experiment V.

If we immerse a piece of tin, lead, bismuth, silver, or gold, in mercury, and draw it out again immediately, the mercury will attract the metal, and the latter will carry with it a portion of the former, which will stick to it so obstinately as to be inseparable by mere friction.

There exists therefore an attraction between the different metals brought in contact with each other.

Experiment VI.

If a small stick be dipt in water, or any other fluid, and drawn out again, a drop will be found hanging at the end of it of a spherical form. The drop is spherical, because each particle of the fluid exerts an equal force in every direction, drawing other particles towards it on every side as far as its power extends.

Thus the very formation of drops obviously demonstrates that there must exist a cause which produces that effect. This cannot be gravity, for agreeable to experience that is rather an obstacle to the formation of drops; since by the weight of the particles, large globules resting on solid bodies are flattened, and their regular spherical form prevented.

To explain this phænomenon there remains only the power of attraction, acting between the particles of the liquid body, for if it is supposed that the particles of a substance reciprocally attract each other with equal force, and their aptitude for being moved upon one another be great enough to overcome any impediment to their motion, it follows by the principles of mechanics, that the equilibrium of the attractive forces can only take place when the mass has received a globular form.

Hence it is that all liquid bodies assume a spherical figure when suffered to fall through the air, or form drops.

Whether the attractions of gravitation and of cohesion, be, or be not considered as essentially the same, is not our business to consider here; there is difference enough between them to allow a very accurate examination of each.

SECT. II.

DIVISION OF ATTRACTION.

THOUGH we are unable to discover the cause of the mutual attraction, experience has proved to us that this agency follows certain conditions or laws; for similar phenomena always present themselves, whenever the circumstances of experiment are the same.

Observation has taught us that attraction takes place between bodies of the same kind, and bodies of a different kind. The first agency is called by physical writers *corpuscular attraction*, or *attraction of aggregation; molecular attraction*; *attraction of cohesion*, or *the cohesive power*.

The latter is termed *chemical attraction, chemical affinity, or affinity of composition*. But before we consider this subject any further we shall give an idea of what has been called *repulsion*.

THEORY

OF

REPULSION.

PART V.

It was mentioned before (page 21) that all matter possesses besides attraction, another power which is in constant opposition to the former. This agency which is equally powerful and equally obvious acts an important part in the phenomena of nature, and is called *the power of repulsion.*

AXIOM
OF
REPULSION.

All bodies are endued with a certain power whose constant tendency is to oppose their approach towards each other, or to remove the particles of matter to a greater distance.

SECT. I.

PROOFS
OF
THE ENERGY OF REPULSION.

THAT there exists a force which opposes the approach of bodies towards each other is evident from numberless facts.

Newton has shown that when a convex lens is put upon a flat glass it remains at a distance of the $\frac{1}{137}$ part of an inch, and a very considerable pressure is required to diminish this distance; nor does any force which can be applied bring them into actual mathematical contact; a force may indeed be applied sufficient to break the glasses into pieces, but it may be demonstrated that it does not diminish their distance much beyond the $\frac{1}{1000}$ part of an inch. There is therefore a repulsive force which prevents the two glasses from touching each other.

Boscowich has shown that when an ivory billiard-ball sets another in motion by striking against it, an equal quantity of its own motion is lost, and the ball at rest begins to move while the other is still at a distance.

There exists therefore a repulsion between bodies; this repulsion takes place while they are yet at a distance from each other; and it opposes their approach towards each other.

The cause or the nature of this force is equally inscrutable with that of attraction, but its existence is undoubted; it increases as far as has been ascertained inversely as the square of the distance, consequently at the point of contact it is infinite.

The following experiments will serve to prove the energy of repulsion more fully.

Experiment I.

We have seen (experiment III. p. 23) that when a glass tube is immersed in water the fluid is attracted by the glass and drawn up into the tube; but if we substitute mercury instead of water we shall find a different effect. If a glass tube of any bore be immersed in this fluid it does not rise, but the surface of the mercury is considerably below the level of that which surrounds it.

In this case therefore a repulsion takes place between the glass and the mercury which is even considerably greater than the attraction existing between the particles of the mercury, and hence the latter cannot rise in the tube, but is repelled, and becomes depressed.

Experiment II.

When we present the north pole of a magnet A, to the same pole of another magnet B, suspended on a pivot, and at liberty to move, the magnet B, will recede as the other approaches; and by following it with A, at a proper distance, it may be made to turn round on its pivot with considerable velocity

In this case there is evidently some agency which opposes the approach of the north poles of A and B, which acts as an antagonist, and causes the moveable magnet to retire before the other. There is therefore a *repulsion* between the two magnets, a repulsion which increases with the power of the magnets; which may be made so great that all the force of a strong man is insufficient to make the two north poles touch each other...The same repulsion is equally obvious on electrical bodies, for instance,

Experiment III.

If two small cork balls be suspended from a body with silk threads so as to touch one another, and if we charge the body in

the usual manner with electricity, the two cork balls separate from each other and stand at a distance proportional to the quantity of electricity with which the body is charged; the balls of course repel each other.

Experiment IV.

If we rub over the surface of a sheet of paper the fine dust of lycopodium or puff ball, and then let water fall on it in small quantities, the water will instantly be repelled and form itself into distinct drops which do not touch the lycopodium, but roll over it with uncommon rapidity. That the drops do not touch the lycopodium but are actually kept at a distance above it, is obvious from the copious reflection of white light.

Experiment V.

If the surface of water contained in a bason be covered over with lycopodium, a solid substance deposited at the bottom of the fluid may be taken out of it with the hand without wetting it. In this case the repulsion is so powerful as to defend the hand completely from the contact of the fluid.

INFERENCES.

The various substances which compose the globe are therefore subject on the one hand, to a general law which tends to unite them together, and on the other hand to another agent which tends to disunite, or to remove them to a greater distance. Hence it is impossible to produce any change whatever in bodies without interrupting these respective agencies.

The great business of the chemist is to examine the changes arising from these agencies, and to trace the laws by which they are regulated. In doing this he investigates the operations of nature, and endeavours to point out their dependencies on one

another. For that purpose he places different bodies in contact with each other, under a diversity of circumstances, and observes the phenomena which accompany their action. He endeavours to trace the conditions under which they are produced, and examines the properties of the new compounds; thus making them subservient to the improvement of the arts, and rendering them the ministers of our necessities, comforts, and enjoyments.

THEORY

OF

CORPUSCULAR ATTRACTION.

OR

ATTRACTION OF AGGREGATION.

PART VI.

1. CORPUSCULAR attraction, or attraction of cohesion or aggregation, is that power by means of which the similar particles of bodies attract each other, and become united into one mass, without changing in the least the chemical properties they possessed before their union. The bodies may be in a solid, fluid, or aeriform state.

2. Corpuscular attraction is different in different bodies. It is always in an inverse ratio to the power of repulsion, or the quantity of caloric interposed between the particles of the acting bodies.

It becomes obvious from this, that the agency of corpuscular attraction consists in a mere successive and constant accumulation of similar particles into one mass; and that it produces adherence of surface, or apparent contact in the ratio of the surfaces.

This force is inherent in all the particles of all bodies (caloric and light perhaps excepted); we never find the particles of bodies in a detached state, but constantly in masses of greater or smaller magnitude, made up of an indefinite number of particles united together by virtue of the force of cohesion.

SECT I.

INSTANCES OF CORPUSCULAR ATTRACTION.

THE simplest case of the exertion of corpuscular attraction is that, where two bodies placed in mutual contact with each other form a direct union, without changing their chemical properties.

Experiment I.

If different particles of sulphur be melted together, they form an uniform mass or whole, the particles of which are held together by virtue of the power of corpuscular attraction, but the properties of the body are not altered.

The same effect takes place when pieces of the same metal, or particles of resin, wax, &c. are united in a similar manner.

Innumerable other instances might be advanced, were not the subject obvious to every one.

MEASUREMENT OF CORPUSCULAR ATTRACTION.

The force of corpuscular attraction in solid bodies may be measured by the weight necessary to demolish it. Thus if a rod of metal, glass, wood, &c. be suspended in a perpendicular direction, and weights be attached to its lower extremity till the rod is broken by them, the weight attached to the rod just before it broke is the measure of the cohesive force of the rod.

SECT. II.

GENERAL LAWS OF CORPUSCULAR ATTRACTION.

LAW I....*The agency of corpuscular attraction acts only at insensible distances; its force* INCREASES *as the distance of the bodies presented to each other* DECREASES, *and as the surfaces of apparent contact are more numerous.*

EXPERIMENT I.

IF we take two sections of a leaden ball, having each a flat and smooth surface, and press them forcibly together, they will cohere, and a considerable effort is necessary to force them asunder.

EXPERIMENT II.

For similar reasons two plates of glass wetted with a little water to fill up their inequalities, when laid together will cohere; and two pieces of marble having each a flat, smooth, and well polished surface, when moistened and slipt upon each other with a gentle pressure, will unite, and a considerable force is required to separate them. But if the two substances placed together, be not sufficiently smooth or polished, it will be in vain to try to cause them to adhere together, for this reason that the particles touch each other only in a few points; whereas on the contrary the particles of the former flat and smooth sur-

faces touch each other in many points. It has been noticed that a silk-worm's thread can be interposed, but not two.

The pressure of the atmosphere has no influence on these experiments, for they succeed equally well *in vacuo* as in the open air.

It is on this account that carpenters, when they intend to glue pieces of wood together, plane the surfaces perfectly smooth before they apply the glue; and that the surfaces of metals are scraped clean before they are soldered, &c.

Hence the corpuscular attraction always vanishes whenever the distance is measurable, and becomes exceedingly great whenever the distance is exceedingly diminished, but the particular rate which this power follows is still unknown, as we have no method of measuring either the distance at which it acts, or its relative intensity.

LAW II....*Corpuscular attraction acts differently in different bodies; according to the degree of force with which it acts between the particles of matter, the bodies appear under different forms.*

1. It is on this account that rock-crystal, flint, diamond and various other precious stones are extremely hard, for the corpuscular attraction unites the particles of these bodies with a great degree of force. Hence a considerable mechanical effort is necessary to disunite them.

2. In blocks of marble, chalk, lime-stone, &c. the particles are held together with a force considerably less. In these bodies it prevents all relative motion among the particles themselves, and hence the motion of one particle is followed by the motion of the whole mass; or if that is impossible, the cohesion is destroyed altogether, and the piece breaks.

3. The integrant parts of wax, tallow, suet, or lard, may be made to change their situations, with a less degree of force than the former.

In these substances the motion of one particle of the body is not necessarily followed by that of all the rest, neither does that motion destroy the cohesion, nor break them.

4. The particles of water, spirit, and ether, move or slide over each other very readily; hence their resistance is considerably less.

5. And lastly, vapours, the air of the atmosphere, and all the gases yield to the slightest possible impulse.

LAW III...*Corpuscular attraction may be annihilated by every effort which tends to separate the particles of bodies.*

It need hardly be mentioned that all mechanical forces, such as grinding, cutting, filing, rasping, pounding, breaking, &c. are of this nature.

In all these cases the force applied must be more than equal to the force of corpuscular attraction; and as it was stated before that the corpuscular attraction acts with different degrees of force between the particles of different bodies, so different degrees of force are necessary to destroy that corpuscular attraction in different bodies.

Hence chalk is more easily reduced to powder than flint; wood is easier broken than lead; lead easier than iron, &c.

ON THE NATURE OF CHEMICAL AFFINITY, OR AFFINITY OF COMPOSITION.

PART VII.

SECT. I.

THEORY OF CHEMICAL AFFINITY.

AFFINITY of composition, or chemical affinity, is that power, by means of which the particles of bodies, whether simple or compound, attract each other so intimately as to produce an uniform whole, totally inseparable by mechanical efforts, and whose characteristic properties are often different, and sometimes contrary to those of its constituent parts.

It is obvious from this, that the particles of those bodies which are united by virtue of chemical affinity, form not a mere aggregate, but an entire new body, which can only be altered by the action of another chemical power.

In considering this kind of affinity, it will be necessary to state;

In what manner it takes place between the particles of different bodies;

In what proportion they are capable of combining;

Under what conditions;

With what degree of force they unite;

And what takes place when a variety of different substances are made to act upon each other at the same time, under certain circumstances and in different proportions.

Hence affinity of composition is of greater importance than corpuscular attraction, or affinity of aggregation, for it takes place in all the complex operations of chemistry.

These topics will form the subject of the following sections.

SECT. II.

INSTANCES

OF

CHEMICAL AFFINITY.

TO prove that chemical affinity acts differently from attraction of aggregation; that it takes place between the ultimate constituent parts of bodies; and that it produces substances possessing properties, frequently very different, and sometimes contrary to those of the constituent parts, the following experiments may serve.

EXPERIMENT I.

Formation of sulphuret of mercury.

Put into a crucible placed in a coal fire, equal parts by weight of sulphur and mercury; stir the two substances together for a few minutes, and when the sulphur is melted, pour the contents out on a marble slab, or piece of glass previously warmed and greased.

The substance obtained by this means is a *sulphuret of mercury*, in which the mercury and sulphur are united by virtue of chemical affinity; for the compound has neither the colour, the splendour, the inflammability, the volatility, nor the specific gravity of either of its constituent parts; nor can the sulphur and mercury be separated by mechanical means; they are therefore chemically united.

Experiment II.

Two malleable and ductile metals, form a brittle alloy.

If we melt together two very malleable and ductile metals, for instance, tin and iron, in equal quantities, the compound produced will have totally lost the properties which its constituent parts possessed before their union, for the alloy formed will be a brittle metal which may easily be broken by the blow of a hammer.

Experiment III.

Blue fluids become changed into red or green, green ones into crimson or purple, &c.

Put two or three tea spoonfuls of an aqueous infusion of red cabbage or syrup of violets, into a wine-glass of water, mix it well, and put half the mixture into another glass. By adding a few drops of sulphuric acid to one of the glasses and stirring it, the blue will be changed to a crimson; and by adding an alcali, for instance potash, to the other glass, the blue fluid will be changed into a green.

If we drop carefully down the sides of the glass into the green obtained in this experiment, a few drops of sulphuric acid, crimson will be perceived at the bottom, purple in the middle, and green at the top. On adding a little alcali to the other glass, containing the crimson, these colours will appear in aninverted order.

Experiment IV.

Two inodorous bodies evolve a very pungent smelling gas.

(Production of ammonia.)

When equal parts of muriate of ammonia and slacked lime, both substances destitute of odour are intimately blended in a stone mortar, a very pungent gas (ammonia) becomes evolved.

Experiment V.

Two odorous and pungent bodies produce a compound destitute of odour.

(Formation of muriate of ammonia.)

Water impregnated with ammonia and concentrated muriatic acid, both fluids of a strong odour, when mixed together in proper proportions, instantly lose their odour, and form a fluid void of smell, (muriate of *ammonia.*)

Experiment VI.

Two fluid bodies produce a solid, when mingled together.

(Formation of sulphate of lime.)

Into a saturated solution of muriate of lime, let fall gradually concentrated sulphuric acid, a quantity of pungent vapour will become disengaged, (muriatic acid gas,) and from the two fluids will thus be produced an almost solid compound, called sulphate of lime.

Experiment VII.

Two solid bodies produce a fluid, by mere mixture.

Let equal parts of fresh crystallized acetite of lead and acidulous sulphate of alumine and potash, be rubbed together intimately in a stone mortar, the saline mixture will soon become soft, and lastly fluid.

A like effect is produced by treating in a similar manner equal parts of crystallized nitrate of ammonia and sulphate of soda.

A solid alloy of mercury and bismuth, and another composed of lead and mercury, on being triturated together instantly become fluid.

It is obvious from this, that when chemical combination takes place, the compound which is formed does not possess properties merely intermediate between those of its component parts, but has acquired others more or less new. This however does not hold good in all cases. There are various combinations in which the properties of bodies are only slightly altered.

SECT. III.

GENERAL LAWS

OF

CHEMICAL AFFINITY.

OBSERVATION has shown that affinity of composition offers certain invariable phenomena, which being founded on a great number of facts are regarded by chemists as laws, and may be reduced under the following heads:

LAW I...*Chemical affinity can exert its action between a number of bodies, simple or compound, and unite them chemically into one whole.*

LAW II...*The efficacy of chemical affinity is in an inverse ratio to that of corpuscular attraction.*

LAW III...*The agency of chemical affinity is influenced by temperature; its action is either accelerated, retarded, prevented, or rendered efficacious.*

LAW IV...*Chemical affinity is accompanied by a change of temperature at the instant of its action.*

LAW V...*The agency of chemical affinity existing between two or more bodies may be dormant, until it is called into action by the interposition of another body which frequently exerts no energy upon any of them in a separate state.*

LAW VI...*The ratio of the energy of chemical affinity acting between various bodies, is different in different substances.*

LAW VII...*The agency of chemical affinity is either limited, or unlimited in certain bodies, in other words: chemical affinity is capable of uniting bodies in definite, or in indefinite proportions.*

LAW VIII...*The energy of the chemical affinity of different bodies is modified in proportion to the ponderable quantities of the bodies placed within the sphere of action.*

Such are the leading laws which regulate the affinity of composition; they may be demonstrated by means of the following experiments.

SECT. IV.

EXPERIMENTAL PROOFS OF THE LAWS OF CHEMICAL AFFINITY.

LAW I...*Chemical affinity can exert its action between a number of bodies, simple or compound, and unite them chemically into one whole.*

PROOFS OF LAW I.

THERE are an infinite variety of compounds, consisting of three, four, five or more simple substances in nature; and art can also effect combinations in which there are many simple bodies chemically united into one whole.

It frequently happens that various separate bodies presented to each other in a fluid, unite and form a single mass, which possesses all the characters of an homogeneous compound, and which retains these characters till its composition has been altered by chemical means.

A considerable number of triple salts are known, which consist of three different substances; for instance, the common alum of commerce consists of sulphuric acid united to alumine and potash or soda. The salt formerly called microcosmic salt or phosphate of soda and ammonia, consists of phosphoric acid united to soda and ammonia, &c. When the oxigenated muriate of mercury is precipitated by the precise quantity of carbonate of soda which is requisite to effect its decomposition, the precipitate obtained contains muriatic acid, carbonic acid, and oxid of mercury in excess.

It is a well known fact that two, three, or more metals may be fused together so as to produce compounds whose properties are widely different from those of the constituent parts.

Experiment I.

Fusible alloys which melt in boiling water.

Melt together in an iron ladle or crucible, eight parts of bismuth, five of lead, and three of tin, the fusibility of the metals will thus be altered, for the alloy melts at 212° Fahr: A spoon or any other utensil formed of this compound will therefore melt in water kept boiling.

If in a similar manner an alloy be made of lead, tin, bismuth, and mercury, their proportions being two, three, five, and one, the compound produced melts at a heat even less than that of boiling water.

A composition of lead, zinc, and bismuth, in equal parts, may be kept in fusion upon paper over a lamp.

Law II...*The efficacy of chemical affinity is in an inverse ratio to that of corpuscular attraction.*

PROOFS OF LAW II.

It was mentioned before that the cohesion of the particles of a body is owing to the mutual affinity existing between them. It is this force which must be overcome by the action of the substance which has a tendency to combine with those particles chemically. The affinity of composition therefore does not become *stronger* as the affinity of aggregation becomes *weaker*, it becomes only *more efficacious;* the absolute powers remain the same; the effect produced by that agency *increases*, because the resistance opposed to it *decreases*.

Remark...It is from this law that it was formerly inferred that some or at least one of the bodies should be in a state of fluidity. This however is by no means necessary. It is in general true, that the weaker the attraction of aggregation is, the more easily the affinity of combination takes place as may be evinced by means of the following experiments:

Experiment I.

Let any quantity of dry carbonate of soda and tartareous acid be mingled together, and put the mixture into a wine-glass, no chemical change will be produced; but if water be added, or either of the salts be previously dissolved, a violent effervescence ensues, and a chemical union is obtained.

The water added is of use merely to overcome the resistance which arises from the cohesion of the particles of the salts intended to be brought into the sphere of action, or to increase their mutual contact.

Experiment II.

If we let fall a crystal, or lump of fluor spar (fluate of lime) into concentrated sulphuric acid, no sensible action will take place, both the sulphuric acid and the fluate of lime remain unaltered; but if the former be reduced to powder, and then brought into contact with the acid, a considerable action instantly takes place, the sulphuric acid unites to one of the constituent parts of the fluor spar, namely, to the lime, and its other constituent part, the fluoric acid, becomes disengaged in the state of white vapour, or fluoric acid gas.

Experiment III.

If crystalized sulphate of alumine, or sulphate of soda, and acetite of lead are brought into contact with each other, the individuality of these bodies will not be destroyed, that is to say, no chemical change will take place; but if they be intimately rubbed

together in a mortar, the two solids will act upon each other and form a fluid.

It is obvious therefore that in order to facilitate chemical affinity, the attraction of aggregation must be broken; the bodies intended to be chemically united must not be presented to each other in their mass of contact, but mechanically divided, or reduced to the smallest moleculæ possible.

Hence liquids combine with more facility than solids, or even than a solid and a liquid, and in like manner vapours combine with rapidity and ease.

LAW III....*The agency of affinity of composition is influenced by temperature. Its action is either accelerated, retarded, prevented, or rendered efficacious.*

PROOFS OF LAW III

EXPERIMENT I.

If we expose phosphorus in an open vessel to the action of the atmosphere, a chemical union will take place between the phosphorus and one of the constituent parts of the atmosphere, namely, the oxigen gas; the phosphorus will gradually (but very slowly) disappear, and become converted into a fluid called phosphorous acid.

But if we heat the vessel containing the phosphorus, the latter will take fire, and become converted into a yellowish white substance, which in a short time is changed into an acid analogous to the former.

EXPERIMENT II.

If equal quantities of muriate of ammonia and carbonate of magnesia are mixt with six or eight parts of water, and suffered to stand for some time exposed to the ordinary temperature of the atmosphere, a mutual decomposition of the two salts will

take place. For if the mixture, and the fluid which passes are left to evaporate spontaneously, muriate of magnesia and carbonate of ammonia will be obtained.

On the contrary,

Experiment III.

If equal quantities of muriate of magnesia and carbonate of ammonia be exposed to a temperature of 200° in about four parts of water, the products obtained are, muriate of ammonia and carbonate of magnesia.

Experiment IV.

If muriate of soda and sulphate of magnesia be mixed together in any proportion, and exposed to a temperature below *zero*, they decompose each other, and muriate of magnesia and sulphate of soda are formed, but no decomposition takes place at a temperature above 30°.

Muriate of soda and acidulous sulphate of alumine and potash, exhibit precisely the same phenomena.

Experiment V.

If ardent spirit and a solution of salt in water be mixt together, the compound formed is a real chemical union; but if we carefully heat the fluid, the caloric applied will be divided between the three ingredients according to their respective affinities; the union will be broken, for the ardent spirit will first become volatilized, and the union of the salt and water remain unaltered. On increasing the temperature, the water will escape in the form of vapour, and the salt will be left behind.

There are numerous cases in which an increase of temperature is essentially necessary to determine bodies to unite. If mercury be exposed to oxigen gas at the common temperature of the atmosphere, the corpuscular attraction subsisting between

its particles is sufficient to prevent combination. But if the mercury be heated to a certain degree, the force which kept its particles united will become annihilated, and it then combines with the oxigen which is present.

Again, if the oxid of mercury thus formed be exposed to a higher degree of temperature, the union is demolished, and the quicksilver re-appears in its metallic state.

Hence it is obvious that the action of caloric favors the union of the oxigen and mercury, in consequence of the diminution of the mutual affinity of the parts ; but at length, by augmenting this difference, it again breaks the union, or renders the combination impossible.

That increased temperature augments the power of chemical union, the solutions of salt and water afford instances of.

A larger quantity of salt is soluble in a given quantity of water at a high, than at a low temperature, and this larger quantity of salt is again separated by cooling.

LAW IV....*Chemical affinity is accompanied by a change of temperature at the instant of its action.*

The truth of this principle will be perceived by applying experiment to theory.

PROOFS OF LAW IV.

EXPERIMENT I.

Production of heat, by the combination of dense acids, alcalis, &c. with water.

We have mentioned already, (page 19) that when equal parts of concentrated sulphuric acid and ardent spirit are mingled to-

gether, the mixture in a few minutes becomes so hot as to render the vessel insupportable to the hands.

If four parts of sulphuric acid of commerce, and one part by weight of water, be mixed together, each at the temperature of 50°, the mixture immediately acquires a temperature of about 300°.

All the dense acids, ammonia, and ardent spirit, when mixed with water, have the property of raising its temperature remarkably: and the same is the case when alcalis are introduced into concentrated acids. On the contrary, in many instances cold is produced.

Experiment II.

Production of extreme degrees of cold.

Take one ounce and a half of muriate of ammonia, and a like quantity of nitrate of potash; reduce each of these salts separately to a powder, and blend them intimately together: having done this, mix them gradually in a glass bason, or other thin glass vessel, with four ounces of water. The result will be, that the cold produced will sink a thermometer immersed in it, to 36° Fahr: A new addition of the same quantity of salts will cool it to 14°, which therefore will freeze water in a glass tube that is immersed in it, without the use of snow or ice. If the water used in a first process be used to reduce other water and salts to the temperature of about 32°, and these be applied to the performance of a second experiment, the temperature may be lowered to 4° below 0°.

A number of experiments have lately been made to produce artificial cold by means of such freezing mixtures. The most complete set of this kind are those of Pepys, Lowitz and Walker. They shall be noticed in the next part of this work.

LAW V...*The agency of chemical affinity between two or more bodies may lie dormant, until it is called into action by the interposition of another body, which frequently exerts no energy upon any of them in a separate state.*

From this law originates what was formerly called disposing affinity, or that case in which two or more bodies are incapable of uniting, until the agency is called into action by the addition of a third body, which exerts no sensible affinity upon either of them.

This may be proved in the following manner.

PROOFS OF LAW V.

Water is a compound of hidrogen and oxigen; phosphorus is a simple body according to our present state of knowledge. If these be presented to each other, no chemical union will take place; but if we add to them an alcali, and then apply heat, the water will become decomposed; that is to say: part of the phosphorus will unite to the oxigen of the water, and form phosphoric acid, and the other part will be dissolved in the hidrogen gas and appear as phosphorated hidrogen.

Here the alcali acts as the substance requisite to favor the mutual action, or to give the disposing affinity.

If iron and water be brought into contact with each other, no perceptible change will be produced; but if a little sulphuric acid be added to the water and iron, a violent effervescence will take place, the water will become decomposed, hidrogen gas will be evolved, and the iron become dissolved in the acid.

In this case the sulphuric acid is the condition necessary to accelerate the chemical action

These experiments will be more fully considered hereafter.

LAW VI....*The ratio of the energy of chemical affinity acting between various bodies, is different in different substances.*

This is the most important law of chemical attraction. As beginners will find it rather difficult to understand what passes in this more complicated agency, we shall shortly remark, that the combination which is effected between two or more bodies by virtue of the affinity of composition, becomes broken whenever we present to the compound another body, which has an attraction to one of the constituent parts of the compound, superior to that attraction by which they were held together: the bodies therefore between which the strongest attraction prevails combine, and the rest are disengaged.

PROOFS OF LAW VI.

EXPERIMENT I.

If muriatic acid be poured either on pure barytes, or on its carbonate, the barytes will be dissolved and the compound will be muriate of barytes, which compound is held together by the force of affinity existing between the muriatic acid and the barytes. On letting fall into this solution a few drops of sulphuric acid, an immediate change of principles takes place; the whole quantity of the muriatic acid which was combined with the barytes becomes disengaged, and the sulphuric acid unites to the barytes with a force equal to their affinity, *minus* that of the muriatic acid.

EXPERIMENT II.

If pure silver be dissolved in pure nitric acid, the silver will remain united to the acid, till another body is presented to it

which has a greater force of attraction to one of the constituent parts of the compound; for instance; if mercury be added to this solution of silver, the mercury will be dissolved, and the silver becomes precipitated or disengaged. The supernatant fluid will then be a *solution of mercury in nitric acid.*

Experiment III.

If to the before obtained solution of mercury in nitric acid, a piece of sheet lead be presented, the lead will be dissolved, and the mercury become precipitated. The fluid will then be a *solution of lead in nitric acid.*

Experiment IV.

If in this solution of lead, a thin slice of copper be suspended, the copper will be dissolved, and the lead will become disengaged. The fluid now is a *solution of copper in nitric acid.*

Experiment V.

If in this solution of copper, a thin sheet of iron be kept immersed, the iron will be dissolved, and the copper become precipitated. The fluid now is a *solution of iron in nitric acid.*

Experiment VI.

If to this solution of iron, a piece of zinc be presented, the zinc will be dissolved, and the iron become precipitated. The solution then consists of *zinc and nitric acid.*

Experiment VII.

If to this solution of zinc in nitric acid some ammonia be gradually added, the ammonia will join to the acid, and the zinc will be precipitated. The solution will then be *nitrate of ammonia.*

Experiment VIII.

If to this solution of nitrate of ammonia, some lime water be added, the ammonia will become disengaged (and manifest itself by a pungent odour) and the solution will be *nitrate of lime*.

Experiment IX.

If to this solution of nitrate of lime some oxalic acid be added, the lime will be precipitated, and what now remains will be merely *nitric acid*.

We see from these experiments that different bodies have different degrees of affinity for one and the same substance, which can only be learnt from observation and experiments.

Remarks...It appears nevertheless from Berthollet's Treatise, as we shall see directly, that in almost all cases of elective affinity, there is not a total transfer of the base, but that a division is made between the two opposite attracting substances, in a compound ratio of the relative force of affinity, and quantity of each; that in many cases the excess of quantity, may supply the deficiency of force, and therefore that the *mass* must be carefully taken into consideration.

Law VII....*The agency of chemical affinity is either limited or unlimited; in other words, chemical affinity is capable of uniting bodies in definite, or in indefinite proportions.*

Experience has convinced us that in all bodies there are certain precise limits of combinations beyond which their action cannot pass, namely a *minimum*, and a *maximum*; it remains still to be ascertained how bodies can combine within these limits.

If we attend to what is known at present, we are forced to acknowledge that this law comprehends several modifications, which may be arranged under the following classes.

1. Chemical affinity unites several bodies in any proportion whatsoever, their combination is therefore unlimited, for instance,

PROOFS OF LAW VII.

Experiment I.

If water and ardent spirit be mingled together in any quantity, a chemical combination ensues, for the compound obtained has always a specific gravity different from the mean specific gravity of the fluids combined. Its bulk is likewise not the arithmetical mean of the fluids in a separate state.

The same is the case when liquid acids and water, or acids and ardent spirit are combined together.

2. Chemical affinity combines several bodies to a certain extent or *maximum* only.

To this class belong all those bodies which are capable of (what is called) saturation.

Experiment II.

If we take a quantity of any of the dense acids diluted with water, for instance sulphuric acid, and let fall into it a solution of an alcali, for example soda, by a little at a time, and examine the mixture after every addition of the alcali, we find for a considerable time it will exhibit the properties of an acid, it will have a sour taste, and convert vegetable blue colours into red; but if we continue to add greater quantities of soda, these acid properties will gradually diminish, and at last disappear altogether. At that point the combination is at an end, it has reached its *maximum* in this case; for if we continue to add more alcali, the mixture will gradually acquire alcaline properties; it

will convert blue vegetables into green; it will have an urinous or alcaline taste, &c. These properties will become stronger the greater the quantity of the soda is which is added.

Experiment III.

Take muriatic acid and let fall into it gradually carbonate of lime or magnesia; an effervescence will take place, for a chemical union ensues between the acid and the lime, or magnesia, and the carbonic acid the other constituent of these bodies, becomes disengaged. But if we continue the addition of the lime or magnesia, until it produces no further effervescence, no chemical union will be obtained, the lime will fall to the bottom unaltered, for the combination is at its *maximum*.

It is on this account that water can only dissolve a certain quaintity of salt; ardent spirit a certain quantity of resin, &c.

The union of oxigen and hidrogen, belongs likewise to this class.

3. Chemical affinity is capable of uniting different bodies in two, three or more proportions; each of these combinations produces compounds possessing peculiar properties.

This peculiarity of combination is highly important.

It is owing to this circumstance that both nature and art produce substances of the same principles only combined in different proportions, which possess peculiar properties widely different from each other.

An instance of this law may be seen in the following

Experiment IV.

Introduce one ounce of copper filings into four ounces of muriatic acid contained in a medicine phial of eight ounces capacity, cork it well and let it stand undisturbed; the acid will soon acquire a greenish colour, which becomes deeper in

proportion as the copper becomes dissolved; but in a few days if the bottle be now and then agitated, the colour vanishes, and the solution at last becomes colourless.

If we now invert the bottle in mercury or water, and remove the cork under that fluid, a quantity of the mercury will rush in. An evident proof that part of the air contained in the phial has disappeared.

If we examine the remaining air, we shall find that it is incapable of supporting flame, and that it is nearly deprived of all its oxigen. If we now open the phial, the solution becomes again green and colourless as before.

The *rationale* of the phenomena are therefore the following: The quantity of oxigen which is present in the confined quantity of air in the empty part of the phial, combines with the copper to a certain degree, which then becomes soluble in the acid, and exhibits the green solution.

This oxid is gradually decomposed, more copper is dissolved, and the solution becomes colourless. If more oxigen be admitted, the solution becomes green again as before.

LAW VIII....*The energy of the chemical affinity of different bodies is modified in proportion to the ponderable quantities of the substances placed within the sphere of action.*

It is obvious from this, that the denomination of elective affinity is erroneous; since it supposes the union of one entire substance with another, in preference to a third. But this is not the case, a mere division of action takes place in instances of this kind; that is to say, the substances act according to the quantity existing within the sphere of activity. The excess of quantity, is capable of compensating for the deficiency of the force of affinity. When therefore a compound body of two substances, is acted on by a third, that part of the compound which is the subject of

combination, is divided between the two remaining not only in proportion to their respective degrees of affinity, but also according to their ponderable quantities, so that by varying this in either, the effect produced will be varied.

Thus Berthollet has proved, that in all cases a large quantity of a body, is capable of abstracting a portion of another, from a small portion of a third, how weak soever the affinity between the first and second of these bodies may be, and how strong soever the affinity between the second and third. Thus potash is capable of abstracting part of the acid from oxalate of lime, phosphate of lime, and carbonate of lime. Soda and lime, decompose partially sulphate of potash. Nitric acid subtracts part of the base from oxalate of lime, &c.

The following experiment advanced by Berthollet will prove this more clearly.

PROOFS OF LAW VIII.

Experiment I.

If equal parts by weight, of sulphate of barytes and potash be boiled in a small quantity of water to dryness, it will be found that the sulphuric acid has been divided between the two bases in the compound ratio of their mass, and their force of affinity. The greater part of the sulphate of barytes will be found undecomposed; a small quantity of barytes will be found at liberty; most of the potash will also be uncombined, but a certain portion will be united with the sulphuric acid which the barytes has lost, in the form of sulphate of potash.

It is not merely in the instance stated here that this division of one body between two others according to their respective masses and affinities takes place, there being scarcely any example to the contrary.

And as the affinities of bodies vary with their masses, it is obvious that when we speak of the affinities of bodies, we ought to consider them as always acting in certain determinate proportions.

INFERENCES....All the tables of affinities in the usual sense of the word, are therefore merely comparative approximations to truth, for they have been constructed upon the supposition that different substances possess different absolute degrees of affinity to each other, capable of producing the decompositions and combinations which offer themselves independently of the proportions of the bodies presented to each other. On the contrary: to determine the elective affinity of different bodies to each other, it is requisite to enquire what are the phenomena which they offer when presented to each other in different proportions. These phenomena have hitherto been little atttended to; nor has much attention been paid to other particular circumstances which appear capable of influencing the agency of affinity in general, namely: the action of light, electricity, galvanism, &c.

When these, and the before-mentioned discovery of Berthollet for determining the relative strength of affinity are more attended to, they will probably lead to consequences of the greatest importance. It will oblige chemists to attend more closely to the reciprocal action of bodies on each other under different circumstances, and the result must be, the discovery of several laws which will greatly facilitate the acquisition and the advancement of the science.

The rapid progress which chemistry has lately made; the multiplicity of its researches; and the scrupulous accuracy of observation with which experiments are now conducted afford us every reason to hope that this will soon be accomplished.

HEAT,

OR

CALORIC.

PART VIII.

HEAT and cold are perceptions of which we acquire the ideas from the senses; they indicate only a certain state in which we find ourselves independent of any exterior object. But as these sensations are for the most part produced by bodies around us, we consider them as causes, and judging by appearances, we apply the terms *hot*, or *cold*, to the substances themselves; calling those bodies *hot*, which produce in us the sensation of heat, and those *cold*, which communicate the contrary sensation.

This ambiguity, though of little consequence in the common affairs of human life, has led unavoidably to confusion and perplexity in philosophical discussions. It was to prevent this, that the framers of the new nomenclature adopted the word CALORIC, which denotes that which produces the sensation of heat.

SECT I.

THEORIES OF HEAT.

TWO opinions have long divided the philosophical world concerning the nature of heat.

1. The one is; that the cause which produces the sensation of heat, is a real, or distinct substance, universally pervading nature, penetrating the particles, or pores of all bodies, with more or less facility, and in different quantities.

This substance, if applied to our system in a greater proportion than it already contains, warms it, as we call it, or produces the sensation of heat; and hence it has been called *caloric* or *calorific*.

2. The other theory concerning heat is; that the cause which produces that sensation, is *not* a separate or self-existing substance; but that it is merely like gravity, a property of matter; and that it consists in a specific or *peculiar motion, or vibration* of the particles of bodies.

The arguments in favour of the first theory have been principally deduced from the evolution, and absorption of heat during chemical combinations; those of the latter, are chiefly founded on the production of heat by friction. For it has been observed that whatever is capable of producing motion in the particles of any mass of matter, excites heat. Count Rumford* and Professor Davy† have paid uncommon attention to this fact, and proved, that heat continues to be evolved from a body subjected to friction, so long as it is applied, and the texture or form of the body, be not altered.

* Rumford's Essays, Vol. III.

† Davy's Essay in Beddoes's Medical Contributions.

All the effects of heat according to this theory, depend therefore entirely on the vibratory motion of the particles of bodies. According as this is more or less intense, a higher, or lower temperature is produced; and as it predominates over...is nearly equal...or inferior to the attraction of cohesion, bodies exist in the gazeous, fluid, or solid state.

Different bodies are susceptible of it in different degrees, and receive and communicate it with different celerity. From the generation, communication and abstraction of this repulsive motion under these laws, all the phenomena ascribed to heat are explicable.

Each of these theories has been supported by the most able philosophers, and given occasion to the most important disputes in which chemists have been engaged; and have contributed in a very particular manner to the advancement of the science. The obscurity of the subject however is such, that both parties have been able to advance the most plausible arguments.

Setting aside all enquiries concerning the merits of these different doctrines, we shall confine ourselves to the general effects, which heat produces on different bodies. For the phenomena which heat presents, and their relation to each other, may be investigated with sufficient precision, though the materiality, or immateriality of it, may remain unknown to us.

NATURE AND THEOREMS OF HEAT.

This premised, those who consider heat as matter, assert that caloric exists in two states, namely, in combination, and in a radiant state or at liberty.

In the first state it is not sensible to our organs, nor indicated by the thermometer; it forms a constituent part of the body; but it may be brought back to the state of radiant or sensible heat. In this state it affects animals with the sensation of heat. It therefore has been called sensible or free heat, or fire; and is synonimous with uncombined caloric, thermometrical caloric,

caloric of temperature, interposed caloric, &c. expressions now pretty generally superseded.

From the diversity of opinions among chemists respecting the nature of caloric several other expressions have been introduced, which it is proper to notice. For instance, by *specific heat* is understood the relative quantities of caloric contained in equal weights of different bodies at the same temperature. *Latent heat* is the expression used to denote that quantity of caloric which a body absorbs when changing its form. It is however more properly called *caloric of fluidity*. The disposition, or property by which different bodies contain certain quantities of caloric, at any temperature, is termed their *capacity for heat*. By the expression of *absolute heat*, is understood the whole quantity of caloric which any body contains. These terms shall be more fully considered hereafter.

Before we proceed further we shall briefly notice the various methods of exciting heat, and then endeavour to examine its general properties.

SECT. II.

METHODS OF EXCITING AND COLLECTING HEAT.

OF the different methods of exciting heat, the following are the most usual:

1. PRODUCTION OF HEAT BY PERCUSSION OR COLLISION.

This method of producing heat is the simplest, and therefore it is generally made use of in the common purposes of life for obtaining fire.

When a piece of hardened steel is struck with a flint, some particles of the metal are scraped away from the mass, and so violent is the heat which follows the stroke, that it melts and vitrifies them. If the fragments of steel are caught upon paper and viewed with a microscope, most of them will be found perfect spherules, and very highly polished. Their sphericity demonstrates that they have been in a fluid state, and the polish upon their surface shows them to be vitrified.

No heat however has been observed to follow the percussion of liquids, nor of the softer kind of bodies which yield to a slight impulse.

2. PRODUCTION OF HEAT BY FRICTION.

Heat may likewise be excited by mere friction. This practice is still retained in some parts of the world. The natives of New Holland are said to produce fire in this manner with great facility, and spread it in a wonderful manner. For that purpose they take two pieces of dry wood, one is a stick about eight or nine inches long, and the other piece is flat; the stick they shape into an obtuse point at one end and pressing it upon the other piece, they turn it very nimbly by holding it between both hands as we do a chocolate mill, often shifting their hands up and then moving them down upon it in order to increase the pressure as much as possible. By this method they get fire in a few minutes and from the smallest spark they increase it with great speed and dexterity.

If the irons at the axis of a coach-wheel are applied to each other without the interposition of some unctuous matter to keep them from immediate contact, they will become so hot when the carriage runs swiftly along as to set the wood on fire; and the fore-wheels being smallest and making most revolutions in a given time will be most in danger.

The same will happen to mill-work or to any other machinery.

It is no uncommon practice in this country for blacksmiths to use a plate of iron as an extemporaneous substitute for a tinder-box; for it may be hammered on an anvil till it becomes red hot, and will fire a brimstone match. A strong man who strikes quick and keeps turning the iron so that both sides may be equally exposed to the force of the hammer, will perform this in less time than would be expected.

If in the coldest season one dense iron plate be laid on another and pressed together by a weight, and then rubbed upon each

other by reciprocal motions, they will gradually grow so hot as in a short time to emit sparks and at last become ignited.

It is not necessary that the substances should be very hard, a cord rubbed backwards and forwards swiftly against a post or a tree will take fire.

Count Rumford* and professor Pictet† have made some very ingenious and valuable experiments concerning the heat evolved by friction.

3. PRODUCTION OF HEAT BY CHEMICAL ACTION.

To this belongs the heat produced by combustion. There are besides this many chemical processes wherein rapid chemical action takes place accompanied with a development of heat, or fire and flame. Instances of this kind have been noticed already, page 19. More striking experiments will be given in the progress of this work.

4. SOLAR HEAT.

It is well known that the solar rays when collected by a mirror or lens into a focus produce the most astonishing effects.

Dr. Herschell has discovered that there are rays emitted from the sun, which have not the power of illuminating or producing vision; and that these are the rays which produce the heat of the solar light.

Consequently heat is emitted from the sun in rays, but these rays are not the same with the rays of light, as shall be more fully proved hereafter.

* Nicholson's Journal (4th Edit.) Vol. II. p. 106.

† Pictet's Essais sur le Feu. Chap. ix.

5. PRODUCTION OF HEAT BY THE ELECTRIC SPARK, AND BY GALVANISM.

The effects of electricity are too well known in this point of view to need any description.

Galvanism has of late become a powerful instrument for the purpose of exciting heat. Not only easily inflammable substances such as phosphorus, sulphur, &c. have been fired, but likewise, gold, silver, copper, tin and the rest of the metals have been burnt by means of galvanism, as was shown by professor Davy in his lectures at the theatre of the Royal Institution in 1801.

Such are the principal methods of exciting heat. We shall now endeavour to examine experimentally the effects which heat produces upon bodies in general.

SECT. III.

GENERAL EFFECTS OF HEAT.

EXPANSIVE PROPERTY OF HEAT.

THIS is the first and most obvious effect which heat produces on bodies. Experience has taught us that at all times when bodies become hot, they increase in bulk. The bodies experience a dilatation which is greater in proportion to the accumulation of caloric, or in other words, to the intensity of the heat. This is a general law which holds good as long as the bodies have suffered no change either in their combination or the quantity of their chemical principles.

This power which heat possesses consists therefore in a constant tendency to separate the particles of bodies. Hence philosophers consider heat as the *repulsive power* which acts upon all bodies whatever, and which is in constant opposition to the power of attraction.

The phenomena which result from these mutual actions seem as it were the secret springs of nature. Heat however does not expand all bodies equally, and we are still ignorant of the laws which it follows.

1. EXPANSION OF FLUID BODIES BY HEAT.

EXPERIMENT I.

Take a glass globe with a long slender neck (called a bolt head) fill it up to the neck with water, ardent spirit, or any other fluid which may be coloured with red or black ink in order to be

more visible and then immerse the globe of the instrument in a vessel of hot water; the included fluid will instantly begin to mount into the neck. If it be taken out of the water and brought near the fire, it will ascend more and more in proportion as it becomes heated; but upon removing it from the source of heat, it will sink again: a clear proof that caloric dilates it, so as to make it occupy more space when hot, than when cold. These experiments may therefore serve as a demonstration that heat expands *fluid* bodies.

It appears that liquids of the least density expand most with the same temperature. Thus hidrogen gas dilates more with the same degree of heat than atmospheric air; atmospheric air more than sulphuric ether; ether more than ardent spirit; ardent spirit more than oil; oil more than water; water more than acids, and acids more than mercury. But if we compare the periods of time necessary for each fluid to acquire the *maximum* of rarefaction it is susceptible of, there is no law to guide us yet known.

2. EXPANSION OF AERIFORM BODIES BY HEAT.

Experiment I.

Take a bladder partly filled with air, the neck of which is closely tied, so as to prevent the inclosed air from escaping, and let it be held near a fire. The air will soon begin to occupy more space, and the bladder will become gradually distended; on continuing the expansion of the air by increasing the heat, the bladder will burst with a loud report.

3. EXPANSION OF SOLID BODIES BY HEAT.

Experiment I.

If we take a bar of iron six inches long and put it into a fire till it becomes red-hot; and then measure it in this state accurately, it will be found $\frac{1}{20}$ of an inch longer than it was before; that

is about 120th part of the whole. That the metal is proportionally expanded in breadth, will be seen by trying to pass it through an aperture which it fitted exactly when cold, but which will not admit it when red-hot. The bar is therefore increased in length and diameter.

To discover the minutest changes of expansion by heat, and the relative proportions thereof, instruments have been contrived called *Pyrometers*, the sensibility of which is so delicate as to show the expansion from $\frac{1}{50000}$ to $\frac{1}{100000}$ of an inch.

INFERENCES.

It is owing to this expansion of metals, that the motion of time-pieces is rendered erroneous; but the ingenuity of artists has discovered methods of obviating this inaccuracy, by employing the greater expansion of one metal to counteract the expansion of another; this is effected in what is called the gridiron pendulum. Upon the same principle a particular construction of watches has been contrived.

The expansion of metals is likewise one of the principal reasons that clocks and watches vary in winter and summer, when worn in the pocket, or exposed to the open air, or when carried into a hotter or a colder climate. For the number of the vibrations of the pendulum, are always in the sub-duplicate ratio of its length, and as the length is changed by heat and cold, the times of vibration will be also changed. The quantity of alteration when considered in a single vibration is exceedingly small, but when they are often repeated it will be very sensible. An alteration of one thousandth part in the time of a single vibration of a pendulum which beats seconds, will make a change of eighty-six whole vibrations in twenty four hours.

As different metals expand differently with the same degree of heat; such musical instruments therefore whose parts are to maintain a constant true proportion, should never be strung with

different metals. It is on this account that harpsichords, &c. are out of tune by a change of temperature.

Bodies which are brittle or which want flexibility crack, or break if suddenly heated or cooled. This likewise depends upon the expansive force of heat, stretching the surface to which it is applied, while the other parts not being equally heated, do not expand in the same ratio, and are therefore torn asunder or break. Hence thin vessels stand heat better than thick ones.

SECT. IV.

MEASUREMENT OF HEAT.

UPON the expansive property of heat, which we have considered before, is founded its artificial measurement. Various means have been therefore employed to assist the imperfection of our sensations in judging of the different degrees of heat, for our feelings unaided afford but very inaccurate information concerning this matter; they indicate the presence of *heat,* only when the bodies presented to them are *hotter* than the actual temperature of our organs of feeling. When those bodies are precisely of the same temperature with our body, which we make the standard of comparison, we then are not sensible of the presence of heat in them. When their temperature is less hot than that of our bodies their contact gives us what is called the sensation of cold.

The effects of heat upon material bodies in general which are easily visible to us, afford more precise and determinate indications of the intensity, than can be derived from our feelings alone. The ingenuity of the philosopher and artist, has therefore furnished us with instruments for measuring the relative heat or temperature of bodies. These instruments are called *Thermometers* and *Pyrometers.* By these all degrees are measurable, from the slightest, to that of the most intense heat.

1. NATURE OF THE THERMOMETER.

A thermometer is a hollow tube of glass, hermetically sealed and blown at one end in the shape of a hollow globe. The

bulb and part of the tube are filled with mercury, which is the only fluid which expands equally. When we immerse the bulb of the thermometer in a hot body, the mercury expands, and of course *rises* in the tube; but when we plunge it into a cold body the mercury contracts and of course *falls* in the tube.

The rising of the mercury indicates therefore an increase of heat; its falling a diminution of it; and the quantity which it rises or falls, denotes the proportion of increase or diminution. To facilitate observation the tube is divided into a number of equal parts, called degrees.

Further, if we plunge a thermometer ever so often into melting snow or ice, it will always stand at the same point. Hence we learn *that snow* or *ice* always begins to melt at the same temperature.

If we plunge a thermometer repeatedly into water kept boiling, we find that the mercury rises up to a certain point. This is therefore the point at which water always boils, provided the pressure of the atmosphere be the same.

There are four different thermometers used at present in Europe, differing from each other in the number of degrees into which the space between the freezing and boiling points is divided. These are Fahrenheit's, Reaumur's, Celsius's, and Delisle's.

The thermometer uniformly used in Britain, is Fahrenheit's; in this the freezing point is fixed at 32°....the boiling point, at 212° above 0°...or the part at which both the ascending and descending series of numbers commence.

In the thermometer which was first constructed by Reaumur, the scale is divided into a smaller number of degrees upon the same length, and contains not more than 80° between the freezing and the boiling points. The freezing point is fixed in this thermometer precisely at 0°, the term between the ascending and the descending series of numbers. 100 is the number of the degrees between the freezing and the boiling points in the

scale of Celsius; which has been introduced into France since the revolution under the name of the Centigrade thermometer; and the freezing point is in this as in the thermometer of Reaumur fixed at 0°. One degree on the scale of Fahrenheit, appears from this account to be equal to $\frac{4}{9}$ of a degree on that of Reaumur, and to $\frac{5}{9}$ of a degree on that of Celsius.

The space in Delisle's thermometer between the freezing and boiling points is divided into 150°, but the graduation begins at the boiling point and increases towards the freezing point. The boiling point is marked 0, the freezing point 150°. Hence 180 F: = 150 D, or 6 F: = 5 D. To reduce the degrees of Delisle's thermometer *under* the boiling point to those of Fahrenheit; we have F: $= 212 - \frac{6D}{5}$; to reduce those *above* the boiling point F: $= 212 + \frac{6D}{5}$. Upon the knowledge of this proportion it is easy for the student to reduce the degrees of any of these thermometers into the degrees of any other of them.

2. NATURE OF THE PYROMETER.

To measure those higher degrees of heat to which the thermometer cannot be applied, there have been other instruments invented by different philosophers, these are called *pyrometers*. The most celebrated instrument of this kind, and which has been adopted into general use, is that invented by the late ingenious Mr. Wedgwood.

This instrument is also sufficiently simple. It consists of two pieces of brass fixed on a plate so as to be $\frac{6}{10}$ of an inch asunder at one end, and $\frac{3}{10}$ at the other; a scale is marked upon them which is divided into 240 equal parts, each $\frac{1}{10}$ of an inch; and with this his gauge, are furnished a sufficient number of pieces of baked clay, which must have been prepared in a red heat, and must be of given dimensions. These pieces of clay, thus prepared, are first to be applied cold, to the rule of the gauge, that there may no mistake take place in regard to their dimensions. Then any one of them is to be exposed to the heat which is to

be measured, till it shall have been completely penetrated by it. It is then removed and applied to the gauge. The difference between its former and its present dimensions, will show, how much it has shrunk; and will consequently indicate, to what degree the intensity of the heat to which it was exposed, amounted.

High temperatures can thus be ascertained with accuracy. Each degree of Wedgwood's pyrometer is equal to 130° of Fahrenheit's.

SECT. V.

EXCEPTIONS TO THE EXPANSION BY HEAT.

PHILOSOPHERS have noticed a few exceptions to the law of heat expanding bodies. For instance; water when cooled down to the freezing point, instead of contracting on the farther deprivation of heat, actually expands.

Another seeming exception is manifested in alumine or clay; others occur in the case of cast-iron, and various other metals. Alumine contracts on being heated, and cast-iron, bismuth, &c. when fully fused are more dense than when solid, for as soon as they become so, they decrease in density, they expand in the act of cooling, and hence the sharpness of figures upon iron which has been cast in moulds, compared to that of other metals.

Some philosophers have persuaded themselves that these exceptions are only *apparent*, but not really true. They say when water freezes, it assumes a crystalline form, the crystals cross each other and cause numerous vacuities, and thus the ice occupies more space. The same is the case with fused iron, bismuth, and zinc. The contraction of clay is owing to the loss of water, of which it loses a part at every increased degree of temperature hitherto tried; there is therefore a loss of matter; and a reduction of volume must follow.

Mr. Tilloch* has published a brief examination of the received doctrines respecting heat and caloric, in which these truths are more fully considered, together with many other interesting facts relative to the received notions of heat.

* Philosophical Magazine, May 1800, p. 78.

SECT. VI.

EQUAL DISTRIBUTION OF HEAT.

IF a number of bodies of different temperatures are placed in contact with each other, they will all at a certain time acquire a temperature, which is the mean temperature of the different substances; the caloric of the hottest body will diffuse itself among those which are heated in a less degree, till they have all acquired a certain temperature. Thus if a bar of iron which has been made red-hot be kept in the open air, it does not retain the heat which it had received but becomes gradually colder and colder, till it arrives at the temperature of the bodies in its neighbourhood. On the other hand; if we cool down the iron bar by keeping it for some time covered with snow, and then carry it into a warm room, it does not retain its low temperature, but becomes gradually hotter till it acquires the temperature of the room. It is therefore obvious that in the one instance the temperature is lowered, and in the other it is raised.

These changes of temperature occupy a longer or a shorter time according to the nature of the body, but they always take place at last. This law itself is indeed familiar to every one: when we wish to heat a body we carry it towards the fire; when we wish to cool it we surround it by cold bodies.

SECT. VII.

PROPAGATION OF HEAT.

WE have seen in the last section that when bodies of higher temperature than others are brought into contact with each other the heat is propagated from the first to the second, or the colder body deprives the warmer of its excess of heat.—We shall now see that some bodies do so much more quickly than others. Through some bodies caloric passes with undiminished velocity, through others, its passage is prodigiously retarded.

This disposition of bodies of admitting under equal circumstances the refrigeration of a heated body within a shorter or a longer time, is called *the power of conducting heat;* and a body is said to be a *better* or *worse conductor of heat,* as it allows the refrigeration to go on quicker or slower. Those bodies therefore which possess the property of letting heat pass with facility are called *good conductors*; those through which it passes with difficulty are called *bad conductors,* and those through which it does not pass at all, are called *non-conductors*: thus we say in the common language, some bodies are *warm* or capable of preserving warmth; and from this arises the great difference in the sensation excited by different bodies, when applied at the same temperature to our organs of feeling. Hence if we immerse our hand in mercury we feel a greater sensation of cold than when we immerse it in water, and a piece of metal appears to be much colder than a piece of wood, though their temperatures when examined by means of the thermometer are precisely the same.

It is probable that all solids conduct heat in some degree, though they differ very much in their conducting power. Metals are the best conductors of heat; but the conducting powers of these substances are by no means equal. Stones seem to be the next best conductors. Glass conducts heat very slowly; wood and charcoal still slower; and feathers, silk, wool, and hair are still worse conductors than any of the substances yet mentioned.

The best conductors of electricity and galvanism are also the best conductors of heat.

Experiment I.

Take a number of straight wires of equal diameters and lengths, but of different metals, for instance, gold, silver, copper, iron, &c. cover each of them with a thin coat of wax or tallow, and plunge their extremities into water kept boiling, or into melted lead. The melting of the coat of wax will show that caloric is more quickly transmitted through some metals than others.

It is on this account also, that the end of a glass rod may be kept red-hot for a long time or even melted without any inconvenience to the hand which holds the other extremity; though a similar metallic rod heated in the same manner would very soon become too hot to be held.

LIQUID AND AERIFORM BODIES CONVEY HEAT BY AN ACTUAL CHANGE IN THE SITUATION OF THEIR PARTICLES.

Count Rumford was the first who proved that fluids in general, and aeriform bodies convey heat on a different principle from that observed in solids. This opinion is pretty generally admitted though various ingenious experiments have been made by different philosophers to prove the contrary. In water for instance which is in the strictest sense of the word a perfect *non-conductor* of heat, the Count has proved that caloric is pro-

pagated only in consequence of the motion which is occasioned in the insulated and solitary particles of that fluid.

All fluids are considered strictly speaking in a similar respect as *non-conductors* of caloric. They can receive it indeed from other substances and can give it to other substances, but no particle can either receive it from, or give it to, another particle. Before a fluid therefore can be heated or cooled every particle must go individually to the substance from which it receives or to which it gives out caloric. Heat being therefore only propagated in fluids in consequence of the internal motion of their particles which transport the heat; the more rapid these motions are, the more rapid is the communication of heat. The cause of these motions is the change in the specific gravity of the fluid, occasioned by the change of temperature, and the rapidity is in proportion to the change of the specific gravity of the liquid by any given change of temperature. The following experiment may serve to illustrate this theory.

Experiment 1.

Take a thin glass tube eight or ten inches long and about an inch in diameter. Pour into the bottom part for about the depth of one inch, a little water coloured with Brazil-wood or Litmus and then fill up the tube with common water, extremely gently, so as to keep the two *strata* quite distinct from each other. Having done this, heat the bottom part of the tube over a lamp, the coloured infusion will then ascend and gradually tinge the whole fluid; the water in the upper part of the tube may be made to boil, but the colouring matter will remain at the bottom undisturbed. The heat cannot act downwards to make it ascend.

By thus being able to make the upper part of a fluid boil without heating the bottom part, water may be kept boiling for a considerable time in a glass tube over ice without melting it.

Other experiments illustrating the same principle may be found in Count Rumford's excellent essays, especially in essay the 7th, 1797.

To this indefatigable philosopher we are wholly indebted for the above facts: he was the first who taught us that air and water were nearly non-conductors. The results of his experiments which are contained in the above essay are highly interesting; they also show that the conducting power of fluids is impaired by the admixture of fibrous and glutinous matter.

Count Rumford proved that ice melted more than 80 times slower when boiling hot water stood on its surface than when the ice was placed to swim on the surface of the hot water. Other experiments showed that water only eight degrees of Fahrenheit above the freezing point, or at the temperature of forty degrees, melts as much ice in any given time, as an equal volume of that fluid at any higher temperature, provided the water stands on the surface of the ice. Water at the temperature of 41° is found to melt more ice, when standing on its surface, than boiling water.

It becomes further evident from the Count's ingenious experiments, that of the different substances used in clothing, hares fur and eider-down are the warmest; next to these, beavers fur, raw silk, sheep's wool, cotton wool, and lastly lint or the scrapings of fine linen. In fur the air interposed among its particles is so engaged as not to be driven away by the heat communicated thereto by the animal body; not being easily displaced it becomes a barrier to defend the animal body from the external cold.

Hence it is obvious that those skins are warmest which have the finest, longest, and thickest fur; and that the furs of the beaver, otter, and other like quadrupeds which live much in the water; and the feathers of water-fowl are capable of confining the heat of those animals in winter, notwithstanding the coldness of the water which they frequent.

Bears, and various other animals, inhabitants of cold climates, which do not often take the water, have their fur much thicker on their backs, than on their bellies.

The snow which covers the surface of the earth in winter in high latitudes is doubtless designed as a garment to defend it against the piercing winds from the polar regions which prevail during the cold season.

Without dwelling farther upon the philosophy of this truth we must briefly remark that the happy application of this law, satisfactorily elucidates some of the most interesting facts of the œconomy of nature.

SECT. VIII.

THEORY OF CALORIC OF FLUIDITY, OR LATENT HEAT.

THERE are some bodies which when submitted to the action of caloric, dilate to such a degree, and the power of aggregation subsisting among their particles is so much destroyed and removed to such a distance by the interposition of caloric, that they slide over each other in every direction, and therefore appear in a fluid state. This phenomenon is called *fusion*. Bodies thus rendered fluid by means of caloric, are said to be *fused*, or *melted*; and those that are subject to it, are called *fusible*.

The greater number of solid bodies, may, by the application of heat, be converted into fluids. Thus metals may be fused; sulphur, resin, phosphorus, may be melted; ice may be converted into water, &c.

Those bodies which cannot be rendered fluid by any degree of heat hitherto known, are called *fixed* or *infusible*.

If the effects of heat under certain circumstances be carried still further than is necessary to render bodies fluid, vaporisation begins; the bodies then become converted into the vaporous or *gazeous state*. Vaporisation however does not always require a previous fusion. Some bodies are capable of being converted into the vaporous state, without previously becoming fluid, and others cannot be volatilized, at any temperature hitherto known.

Fluidity is therefore by no means essential to any species of matter, but always depends on the presence of a quantity of ca-

loric. Solidity is the natural state of all bodies, and there can be no doubt that every fluid is capable of being rendered solid by a due reduction of temperature; and every solid may be fused by the agency of caloric, if the latter does not decompose them at a temperature inferior to that which would be necessary for their fusion.

CALORIC OF FLUIDITY.

Dr. Black was the first who proved that whenever caloric combines with a solid body, the body becomes heated only, until it is rendered fluid; or that whenever it has acquired the fluid state, its temperature remains stationary, though caloric is continued to be added to it. The same is the case when fluids are converted into the aeriform or vaporous state.

From these facts the laws of latent heat have been inferred. The theory may be illustrated by means of the following experiments:

Experiment I.

If a lump of ice, at a low temperature, suppose at 22°, be brought into a warm room, it will become gradually less cold, as may be discovered by means of a thermometer. After a very short time it will reach the temperature of 32°; (the freezing point) but there it stops. The ice then begins to melt; but the process goes on very slowly. During the whole of that time its temperature continues at 32°; and as it is constantly surrounded by warm air, we have reason to believe that caloric is constantly entering into it; yet it does not become hotter till it is changed into water. Ice therefore is converted into water by a quantity of caloric uniting with it.

It has been found by calculation that one pound of ice in melting absorbs 140° of caloric, the temperature of the water produced still remaining at 32°.

This fact may be proved in a direct manner.

Experiment II.

Take one pound of ice at 32° reduced to a coarse powder, put it into a wooden bowl, and pour over it gradually, one pound of water heated to 172°, all the ice will become melted, and the temperature of the whole fluid, if examined by a thermometer, will be 32°; 140° of caloric are therefore lost, and it is this quantity which was requisite to convert the ice into water.

This caloric has been called *latent caloric*, or rather, caloric of fluidity, because its presence is not measurable by the thermometer.

Dr. Black has also ascertained by experiment, that the fluidity of melted wax, tallow, spermaceti, metals, &c. is owing to the same cause, and Ladriani proved that this is the case with sulphur, alum, nitrate of potash, &c.

We consider it therefore as a general law, that whenever a solid is converted into a fluid, it combines with caloric, and that is the cause of fluidity.

On the sudden transition of solids into fluids, is founded the well known

PRODUCTION OF ARTIFICIAL COLD,

BY MEANS OF

FRIGORIFIC MIXTURES.

A number of experiments have been lately made by different philosophers, in order to produce artificial cold. And as these methods are often employed in chemistry with a view to expose bodies to the influence of very low temperatures, we shall enumerate the different substances which may be made use of for that purpose, and the degrees of cold which they are capable of producing. We are indebted for them to Pepys, Walker, and Lowitz.

TABLE

OF

FREEZING MIXTURES.

Mixtures.	*Thermometer sinks.*
Muriate of ammonia. 5 parts Nitrate of potash..... 5 Water.....16	From 50° to 10°
Muriate of ammonia. 5 parts Nitrate of potash..... 5 Sulphate of soda..... 8 Water.....16	From 50° to 4°.
Sulphate of soda..... 3 parts Diluted nitric acid... 2	From 50° to 3°.
Sulphate of soda..... 8 parts Muriatic acid..... 5	From 50° to 0°.
Snow..... 1 part Muriate of soda..... 1	From 32° to 0°.
Snow or pounded ice. 2 parts Muriate of soda..... 1	From 0° to −5.
Snow or pounded ice. 1 parts Muriate of soda..... 5 Muriate of ammonia & Nitrate of potash..... 5	From −5° to−18°.

TABLE

OF

FREEZING MIXTURES.

Mixtures.	*Thermometer sinks.*
Snow or pounded ice 12 parts Muriate of soda 5 Nitrate of ammonia 5	From — 18° to — 25°.
Snow and Diluted nitric acid	From 0° to — 46°.
Muriate of lime 3 parts Snow 2	From 32° to —50°.
Potash 4 parts Snow 3	From 32° to — 51°.
Snow 2 parts Diluted sulphuric acid 1 Diluted nitric acid 1	From — 10° to — 56°.
Snow 1 part Diluted sulphuric acid 1	From 20° to —60°.
Muriate of lime 2 parts Snow 1	From 0° to — 66°.
Muriate of lime 3 parts Snow 1	From — 40° to — 73°.

TABLE

OF

FREEZING MIXTURES.

Mixtures.	*Thermometer sinks.*
Diluted sulphuric acid 10 parts Snow..... 8	From — 68° to — 91°.
Nitrate of ammonia.. 1 part Water.....1	From 50° to 4°.
Nitrate of ammonia...1 part Carbonate of soda.... 1 Water.....1	From 50° to 3°.
Sulphate of soda..... 6 parts Muriate of ammonia.. 4 Nitrate of potash.....2 Diluted nitric acid....4	From 50° to 10°.
Sulphate of soda.....6 parts Nitrate of ammonia.. 5 Diluted nitric acid....4	From 50° to 14°.
Phosphate of soda.... 9 parts Diluted nitric acid....4	From 50° to 12°.
Phosphate of soda.... 9 parts Nitrate of ammonia.. 6 Diluted nitric acid....4	From 50° to 21°.
Sulphate of soda.....5 parts Diluted sulphuric acid 4	From 50° to 3°.

MANAGEMENT
OF
THE PRECEDING MIXTURES
FOR
PRODUCING COLD.

To produce the effects before stated, the salts must be reduced to powder, and contain their full quantity of water of crystallisation. The vessel in which the freezing mixture is made should be very thin, and just large enough to hold it, and the materials should be mixed together as expeditiously as possible, taking care to stir the mixture at the same time with a rod of glass or wood.

In order to obtain the full effect, the materials ought to be first cooled to the temperature marked in *the table,* by introducing them into some of the other frigorific mixtures, and then mingling them together in a similar mixture. If, for instance, we wish to produce $= -46°$, the snow and diluted nitric acid ought to be cooled down to 0°, by putting the vessel which contains each of them into the fifth freezing mixture in the above table before they are mingled together. If a more intense cold be required, the materials to produce it are to be brought to the proper temperature by being previously placed in the second freezing mixture.

This process is to be continued till the required degree of cold has been procured.

SECT. IX.

CONVERSION OF SOLIDS AND FLUIDS INTO THE AERIFORM OR GAZEOUS STATE.

WE have seen before that in order to render solids fluid, a certain quantity of caloric is necessary, which combines with the body, and therefore cannot be measured by the thermometer; we shall now endeavour to prove, that the same holds good in respect to the conversion of solids or fluids into the vaporous or gazeous state.

CONVERSION OF SOLIDS INTO THE GAZEOUS STATE.

Experiment I.

Take a small quantity of carbonate of ammonia, introduce it into a retort the neck of which is directed under a cylinder filled with mercury and inverted in a bason of the same fluid. On applying heat to the body of the retort, the carbonate of ammonia will be volatilised, it will expel the mercury out of the cylinder, and become an invisible gas, and would remain so, if its temperature was not lowered.

The same is the case with benzoic acid, camphor, and various other substances.

SECT. X.

CONVERSION

OF

FLUIDS INTO THE GAZEOUS STATE.

ALL fluids may by the application of heat be converted into an aeriform elastic state.

When we consider water in a boiling state, we find that this fluid when examined by the thermometer, is not hotter after boiling several hours, than when it began to boil, though to maintain it boiling a brisk fire must necessarily be kept up. What then we may ask becomes of the wasted caloric? It is not perceptible in the water, nor is it manifested by the steam; for the steam, if not compressed, upon examination is found not to be hotter than boiling water. The caloric is therefore absorbed by the steam, and although what is so absorbed, is absolutely necessary for the conversion of water into the form of steam; it does not increase its temperature, and is therefore not appreciable by the thermometer.

This conclusion is further strengthened by the heat given out by steam on its being condensed by cold. This is particularly manifested in the condensation of this fluid in the process of distilling, where upon examining the refrigeratory, it will be found that a much greater quantity of caloric is communicated to it, than could possibly have been transmitted by the caloric which was sensibly acting before the condensation. This may be easily ascertained by observing the quantity of caloric communicated to the water in the refrigeratory of a still, by any given quantity of liquid that passes over.

1. *The boiling points of different fluids are influenced by atmospheric pressure.*

The boiling point or the conversion of fluids into gases always takes place at certain temperatures, which is different in different fluids provided the pressure of the atmosphere be the same.

Experiment I.

Put any quantity of sulphuric ether into a Florence flask, suspend a thermometer in it, and hold the flask over an Argand's lamp, the ether will immediately begin to boil and the thermometer will indicate 98°, if the ether has been highly rectified.

Experiment II.

If highly rectified ardent spirit is heated in a similar manner, the thermometer will rise to 176°, and there remain stationary.

Experiment III.

If water is substituted it will rise to 212°.

Experiment IV.

If strong nitrous acid of commerce be made use of, it will be found to boil at 248°;—sulphuric acid at 546°;—and mercury and linseed-oil at 600°, &c.

2. *The boiling point of fluids is retarded by pressure.*

Mr. Watt heated water under a strong pressure to 400°. Yet still when the pressure was removed only part of the water was converted into vapour, and the temperature of this vapour, as well as that of the remaining fluid, was no more than 212°. There was therefore 188° of caloric suddenly lost. This caloric was carried off by the steam. Now as only about $\frac{1}{5}$ of the water

was converted into steam, that steam must contain not only its own 188°, but also the 188° lost by each of the other four parts; that is to say, it must contain $188° \times 5$, or about 940°. Steam therefore, is water combined with at least 940° of caloric, the presence of which is not indicated by the thermometer.

3. *When pressure is removed from the surface of bodies their conversion into the gazeous state is greatly facilitated, or their boiling point is lowered.*

In proof of this the following experiments may serve:

Experiment I.

Let a small bottle be filled with highly rectified sulphuric ether, and a piece of wetted bladder be tied over its orifice around its neck. Transfer it under the receiver of an air-pump and take away the super-incumbent pressure of the air in the receiver. When the exhaustion is compleat, pierce the bladder by means of a pointed sliding wire, passing through a collar of leather which covers the upper opening of the receiver. Having done this, the ether will instantly begin to boil, and become converted into an invisible gazeous fluid.

Experiment II.

Take a small retort or Florence flask, fill it one half or less with water, and make it boil over a lamp; when kept briskly boiling for about five minutes, cork the mouth of the retort as expeditiously as possible, and remove it from the lamp.

The water on being removed from the source of heat, will keep boiling for a few minutes, and when the ebullition begins to slacken, it may be renewed by dipping the retort into cold water.

The water during boiling becomes converted into vapour, this vapour expels the air of the vessel and occupies its place; on diminishing the heat, it condenses; when the retort is stopped, a partial vacuum is formed; the pressure becomes diminished, and a less degree of heat is sufficient to cause an ebullition.

For the same reason water may be made to boil under the exhausted receiver at 94° Fahr. or even at a much lower degree; alcohol at 56°, and ether at — 20°.

On the conversion of fluids into gases is founded the following experiment:

Experiment III.

To freeze water by means of sulphuric ether.

Take a thin glass tube 4 or 5 inches long and about two or three eighths of an inch in diameter, and a two ounce bottle furnished with a capillary tube fitted to its neck. In order to make ice, pour a little water into the tube, taking care not to wet the outside, nor to leave it moist. Having done this, let a stream of sulphuric ether fall through the capillary tube upon that part of it containing the water, which by this means will be converted into ice in a few minutes, and this it will do even near a fire or in the midst of summer.

If the glass tube containing the water be exposed to the brisk thorough air, or free draught of an open window, a large quantity of water may be frozen in a shorter time; and if a thin spiral wire be introduced previous to the congelation of the water, the ice will adhere to it, and may thus be drawn out conveniently.

A person might be easily frozen to death during very warm weather, by merely pouring upon his body for some time sulphuric ether, and keeping him exposed to a thorough draught of air.

ARTIFICIAL REFRIGERATION.

The cooling or refrigeration of rooms in the summer season by sprinkling them with water becomes likewise obvious on this account.

The method of making ice artificially in the East Indies

Depends on the same principle. The ice-makers at *Benares* dig pits in large open plains, the bottom of which they strew with sugar canes or dried stems of maize or Indian corn. Upon this bed they place a number of unglazed pans, made of so porous an earth that the water penetrates through their whole substance. These pans are filled towards evening in the winter season with water that has boiled, and left in that situation till morning, when more or less ice is found in them, according to the temperature of the air; there being more formed in dry and warm weather, than in that which is cloudy, though it may be colder to the human body.

Every thing in this process is calculated to produce cold by evaporation, the beds on which the pans are placed suffer the air to have a free passage to their bottoms, and the pans constantly oozing out water to their external surface, are cooled by the evaporation of it.

In Spain, they use a kind of earthen jars, called buxaros, which are only half-baked, the earth of which is so porous, that the outside is kept moist by the water which filters through it, and though placed in the sun, the water in the jar becomes as cold as ice.*

It is a common practice in China to cool wine or other liquors by wrapping the bottle in a wet cloth, and hanging it up in the sun. The water in the cloth becomes converted into vapour, and thus cold is produced.

* Twiss's travels through Portugal and Spain.

The blacks in Senegambia have a similar method of cooling water by filling tanned leather bags with it, which they hang up in the sun; the water oozes more or less through the leather so as to keep the outward surface wet, which by its quick and continued evaporation cools the water remarkably.

The winds on the borders of the Persian Gulph are often so scorching, that travellers are suddenly suffocated unless they cover their heads with a wet cloth; if this be too wet they immediately feel an intolerable cold which would prove fatal if the moisture was not speedily dissipated by the heat.

If a cold vessel is brought into a warm room, particularly where many people are assembled, the outside of it will soon become covered with a sort of dew.

Before some changes of weather the stone pavements, the walls of a house, the balustrades of stair-cases and other solid objects feel clammy and damp.

In frosty nights, when the air abroad is colder than the air within, the dampness of this air, for the same reason, settles on the glass panes of the windows and is there frozen into curious and beautiful figures.

Thus *fogs* and *dews* take place, and in the higher regions *clouds* are formed from the condensed vapour. The still greater condensation produces *mists* and *rain*.

SECT. XI.

CAPACITY OF BODIES FOR CONTAINING HEAT.

THE property which different bodies possess, of containing at the same temperature, and in equal quantities, either of mass or bulk, unequal quantities of heat, is called their capacity for heat. The capacities of bodies for heat are therefore considered as great or small in the ratio as their temperatures are either raised or lowered by the addition, or diminished by the deprivation of equal quantities of heat.

In homogeneous bodies the quantities of caloric which they contain are in the ratio of their temperature and quantity of mass; for instance, when equal quantities of water, oil, or mercury, of unequal temperatures are mingled together the temperature of the whole will be the *arithmetical* mean between the temperatures of the two quantities that had been mixed together. It is a self-evident truth that this should be the case, for the particles of different portions of the same substance being alike, their effects must be equal. For instance.

EXPERIMENT I.

Mix a pound of water at 172° with a pound at 32°, half the excess of heat in the hot water will quit it to go over into the

colder portion; thus the hot water will be cooled 70°, and the cold will receive 70° of temperature; therefore 172 — 70, or 32 + 70 = 102 will give the heat of the mixture. To attain the arithmetical mean very exactly, several precautions however are necessary.*

When heterogeneous bodies of different temperatures are mixt together, the temperature produced is never the arithmetical mean of the two original temperatures.

In order to ascertain the comparative quantities of heat of different bodies, equal weights of them are mingled together; the experiments for this purpose being in general more easily executed than those by which they are compared from equal bulks.

Experiment I.

If one pound of mercury heated to 110° Fahr: be added to one pound of water of 44°, the temperature of the blended fluids will not be changed to 77°, as it would be if the surplus of heat were divided among those fluids in the proportion of their quantities. It will be found on examination to be only 47°.

Experiment II.

On the contrary; if the pound of mercury be heated to 44° and the water to 110° then on stirring them together the common temperature will be 107°.

Hence if the quicksilver loses by this distribution 63° of caloric, an equal weight of water gains only 3° from this loss of 63° of heat. And on the contrary, if the water loses 3° the mercury gains 63°.

When, instead of comparing the quantities of caloric which equal *weights* of different bodies contain, we compare the quan-

* Crawford on Animal Heat, p. 95, &c.

tities contained in equal *volumes,* we still find that the same difference takes place. Thus it is found by experiment, that the quantity of caloric necessary to raise the temperature of a given volume of water any number of degrees, is to that necessary to raise an equal volume of mercury the same number of degrees as 2 to 1. This is therefore the proportion between the comparative quantities of caloric which these two bodies contain, estimated by their volumes; and similar differences exist with respect to every other kind of matter.

From the nature of the experiments by which the quantities of caloric which bodies contain are ascertained, it is evident that we discover merely the *comparative,* not the *absolute* quantities. Hence water has been chosen as a standard, to which other bodies may be referred; its capacity is stated as the arbitrary term of 1000, and with this the capacities of other bodies are compared.

It need not be told that pains have been taken to estimate on these experiments that portion of heat which diffuses itself into the air or into the vessel where the mercury and water are blended together. As however such valuations cannot be made with complete accuracy, the numbers stated above are only an approximation to truth.

SECT. XII.

RADIATION OF CALORIC.

CALORIC is thrown off or radiates from heated bodies in right lines, and moves through space with inconceivable velocity. It is retarded in its passage by atmospheric air, by colourless fluids, glass, and other transparent bodies.

For if a glass mirror be placed before a fire, the mirror transmits the rays of light, but not the rays of heat.

If a plate of glass, talc, or a glass vessel filled with water be suddenly interposed between the fire and the eye, the rays of light pass through it, but the rays of caloric are considerably retarded in its passage; for no heat is perceived until the interposed substance is saturated with heat, or has reached its *maximum*. It then ceases to intercept the rays of caloric, and allows them to pass as freely as the rays of light.

It has been lately shewn by Dr. Herschel that the rays of caloric are refrangible, but less so than the rays of light; and the same philosopher has also proved by experiment, that it is not only the rays of caloric emitted by the sun, which are refrangible, but likewise the rays emitted by common fires, by candles, by heated iron, and even by hot water.

Whether the rays of caloric are differently refracted, in different mediums, has not yet been ascertained. We are certain

however, that they are refracted by all transparent bodies which have been employed as burning glasses.

The rays of caloric are also reflected by polished surfaces, in the same manner as the rays of light.

This was long ago noticed by Lambert, Saussure, Scheele, Pictet, and lately by Dr. Herschel.

Professor Pictet placed two concave metallic mirrors opposite to each other at the distance of about twelve feet. When a hot body, an iron bullet for instance, was placed in the focus of the one, and a mercurial thermometer in that of the other, a substance radiated from the bullet; it passed with incalculable velocity through the air, it was reflected from the mirrors, it became concentrated, and influenced the thermometer placed in the focus, according to the degree of its concentration.

An iron ball two inches in diameter, heated so that it was not luminous in the dark, raised the thermometer not less than ten and a half degrees of Reaumur's scale, in six minutes.

A lighted candle occasioned a rise in the thermometer nearly the same.

A Florence flask containing two ounces and three drachms of boiling water, raised Fahrenheit's thermometer three degrees. He blackened the bulb of his thermometer and found that it was more speedily influenced by the radiation than before, and that it rose to a greater height.

M. Pictet discovered another very singular fact; namely the *apparent radiation of cold.* When instead of a heated body, a Florence flask full of ice or snow is placed in the focus of one of the mirrors, the thermometer placed in the focus of the other immediately descends, and ascends again whenever the cold body is removed.

This phenomenon may be explained on the supposition, that from every body at every temperature caloric radiates, but in less quantity as the temperature is low; so that in the above experiment, the thermometer gives out more caloric by radiation, than it receives from the body in the opposite focus, and there-

fore its temperature is lowered. Or as Pictet has supposed, when a number of bodies near to each other have the same temperature, there is no radiation of caloric, because in all of them it exists in a state of equal tension; but as soon as a body at an inferior temperature is introduced, the balance of tension is broken, and caloric begins to radiate from all of them till the temperature of that body is raised to an equality with theirs. In the above experiment therefore, the placing the snow or ice in the focus of the mirror causes the radiation of caloric *from* the thermometer, and hence the diminution of temperature which it suffers.

These experiments have been lately repeated by Dr. Young and Professor Davy, at the theatre of the Royal Institution. These gentlemen inflamed phosphorus by reflected caloric; and proved that the heat thus excited was very sensible to the organs of feeling.

It is therefore evident that caloric is thrown off from bodies in rays, which are invisible, or incapable of exciting vision, but which are capable of exciting heat.

These invisible rays of caloric are propagated in right lines, with extreme velocity, and are capable of the laws of reflection and refraction.

The heating agency however is different in the different coloured rays of the prismatic spectrum. According to Dr. Herschel's experiments it follows inversely the order of the refrangibility of the rays of light. The least refrangible, possessing it in the greatest degree.

Sir Henry Englefield has lately made a series of experiments on the same subject, from which we learn that a thermometer having its ball blackened, rose when placed in the *blue* ray of the prismatic spectrum in 3′ from 55° to 56°; in the *green*, in 3′ from 54° to 58°; in the *yellow*, in 3′ from 56° to 62°; in the *full red* in $2\frac{1}{2}$′ from 56° to 72°; in the *confines of the red*, in

$2\frac{1}{2}'$ from 58° to $73\frac{1}{2}°$; and *quite out of the visible light* in $2\frac{1}{2}'$ from 61° to 79°.

Between each of the observations, the thermometer was placed in the shade so long as to sink it below the heat to which it had risen in the preceding observation, of course its rise above that point, could only be the effect of the ray to which it was exposed. It was continued in the focus long after it had ceased to rise; therefore the heats given are the greatest effects of the several rays on the thermometer in each observation. A thermometer placed constantly in the shade near the apparatus, was found scarcely to vary during the experiments.

Sir Henry made other experiments with thermometers with naked balls, and with others, whose balls were painted white, for which we refer the reader to the interesting paper of the baronet,* from which the above experiments are transcribed.

The coloured rays emitted from the sun and combustible bodies, since they excite heat and vision, must consist of a mixture of heat-making rays, and rays of light.

And as the rays of heat and light accompany each other when emitted from luminous bodies, the velocity with which the rays of caloric move must be equal to that of light, and hence its particles must be equally minute. They differ however in this particular, that the rays of light produce the sensation of vision, and possess certain chemical properties, whilst in those of caloric the peculiar agency of heat resides.

* Journals of the Royal Institution, No. x, p. 202.

LIGHT.

PART IX.

THE nature of light has occupied much of the attention of thinking men, and numerous opinions have been entertained concerning it. It has been sometimes considered as a distinct substance, at other times as a quality; sometimes as a cause, frequently as an effect; by some it has been considered as a compound, by others as a simple substance. Philosophers of the present day are not agreed as to the independent existence of light, or the cause by which we see.

This is not the place for discussing the respective merits of all the ingenious hypotheses, which have been advanced concerning this subject, we shall assume the doctrine of those, who admit the independent existence of light, not only because it is more generally received, but is also best calculated to explain its chemical properties.

SECT. I.

NATURE OF LIGHT.

LIGHT is that which proceeds from any body producing the sensation of vision, or perception of other bodies, by depicting an image of external objects on the retina of the eye. Hence it announces to animals the presence of the bodies which surround them, and enables them to distinguish these bodies into transparent, opaque, and coloured. These properties are so essentially connected with the presence of light, that bodies lose them in the dark, and become undistinguishable.

Light is regarded by philosophers as a substance consisting of a vast number of exceedingly small particles, which are actually projected from luminous bodies, and which probably never return again to the body from which they were emitted.

It is universally expanded through space. It exerts peculiar actions, and is obedient to the laws of attraction, and other properties of matter.

1. EXPLANATION OF CERTAIN TERMS OF LIGHT.

In order to facilitate the doctrine of light, we shall shortly explain a few terms made use of by philosophers when treating of it; namely:

A *ray of light* is an exceedingly small portion of light as it comes from a luminous body.

A *medium* is a body which affords a passage for the rays of light.

A *beam of light* is a body of parallel rays.

A *pencil of rays* is a body of diverging or converging rays.

Converging rays are rays which tend to a common point.

Diverging rays are those which come from a point, and continually separate as they proceed.

The rays of light are *parallel,* when the lines which they describe are so.

The radiant point is the point from which diverging rays proceed.

The *focus* is the point to which the converging rays are directed.

2. SOURCES OF LIGHT.

Light is emitted from the sun, the fixed stars, and other luminous bodies. It is produced by percussion, during electrisation, combustion, and in various other chemical processes.

Why the sun and stars are constantly emitting light, is a question which probably will for ever baffle human understanding; at any rate it is not connected with chemistry.

The light emitted during combustion exists previously either combined with the combustible body, or with the substance which supports the combustion. The light liberated during chemical action, formed a constituent part of the bodies which act on each other. The light emitted during percussion and electrisation, &c. is foreign to our subject.

SECT. II.

PHYSICAL PROPERTIES OF LIGHT.

1. VELOCITY OF LIGHT.

THE velocity of light is much greater than that of sound, for the flash of a gun fired at a considerable distance, is seen before the report is heard.

The clap of thunder is not heard till some time after the lightning has been seen, except the phenomena takes place at no great distance.

The motion of light is so very rapid that in all common experiments it appears to be instantaneous. Its velocity cannot be measured between the tops of the most distant mountains that are visible from each other. Astronomers have nevertheless found that it *may* be measured when it moves between some of the heavenly bodies. For by the eclipses of Jupiter's satellites, it appears that it takes 8 minutes and 13 seconds in passing across the semidiameter of the earth's orbit. From these accurate investigations they have deduced that light passes with a velocity of about 167,000 geographical miles, in one second, or that it passes from the sun to the earth in little more than eight minutes.

This observation, which was first made by Roemer, has been confirmed by Dr. Bradley's ingenious Theory of the Aberration of the Lights of the fixed Stars.*

2. MOMENTUM AND MAGNITUDE OF THE PARTICLES OF LIGHT.

The velocity of light being thus ascertained, we should be enabled to form some notion of the magnitude of the particles of light, if we were in possession of good observations on the effect of their momentum.

For example; it is found that a ball from a cannon at its first discharge flies with a velocity of about a mile in eight seconds, and would therefore arrive at the sun in thirty-two years, supposing it to move with unremitted celerity. Now light moves through that space in about eight minutes, which is two million times faster. But the forces with which bodies move are as their masses multiplied by their velocities: If therefore the particles of light were equal in mass to the two millionth part of a grain of sand, we should be no more able to endure their impulse, than that of sand when shot point-blank from the mouth of a cannon.† How much less must therefore be the particles of light, which makes no sensible impression upon so delicate an organ as the eye.

3. LIGHT MOVES IN STRAIGHT LINES.

Whenever light passes through a space occupied by a medium of uniform density, it describes right lines in all directions.

* Philosoph. Trans. xxxv. p. 637, and xix. p. 1.

† Nicholson's Introd. to Natural Philosophy, vol. I. p. 256.

It is well known that if a portion of a beam of light be intercepted by any body, the shadow of that body will be bounded by right lines, passing from the luminous body, and meeting the lines which terminate the opaque body.

Experiment I.

Darken a room into which the sun shines and only admit the light by a small hole in the window shutter; and place opposite to the hole a board or screen. If we look at the screen we observe thereon, a picture of all the exterior objects which are opposite to the hole in all their natural colours: these colours are faintly depicted; the images of the objects that are stationary, as houses, trees, &c. are likewise fixed or stationary in the picture; whilst the images of those that are in motion, as those of horses, carriages, &c. are seen to move. If we place our eye, in this ray, we find that our eye, the light and the hole, are in one and the same straight line. Which is a clear proof that light is emitted in straight lines, by the luminous bodies

It is equally obvious from light finding no passage through bent or crooked tubes.

4. REFLECTION OF LIGHT.

Another property of the rays of light is their *reflexibility* or disposition of being turned back into the medium in which they moved with a certain obliquity, so that the light is driven back, without coming into contact with the matter which repels it.

The ray is then said to be *reflected*. The angle of reflection is always equal to the angle of incidence.

When a ray of light falls upon a polished medium, for instance a plate of glass or mirror with a certain obliquity, it does not enter the glass at all, but is reflected when it approaches its surface. When a ray of light enters other transparent *media* it con-

tinues to move on till it comes to the opposite surface; but then instead of passing through, it bends and passes out again at the same surface at which it entered; just as a ball would do if made to strike obliquely against a floor.

Experiment I.

Let a beam of solar light pass into a darkened room through a hole in the window-shutter; at that part of the floor, where the beam of light falls, place a looking-glass, and then throw some hair-powder into the air in order to render the beam of light more visible:

We shall then see that the beam is reflected back into the air, and that the inclination of the reflected beam, is exactly the same as that of the incidental one.

The common experiment of children casting the light of the sun, by means of a looking-glass, into various distant places, also illustrates this property.

5. INFLECTION OF LIGHT.

When a ray of light passes within a certain distance of a body, parallel to which it is moving, it is attracted, or bent *towards* it. This inflection is caused by an attractive power to which the light is obedient.

Experiment I.

Admit a beam of light into a dark room, through a round hole in the window-shutter and place at the spot on the floor where it falls a sheet of paper, the rays of light will there form a round luminous spot. But if we bring two pen-knives, with their edges towards each other, on opposite sides of the hole, and make them approach each other gradually, the luminous spot will dilate itself on the sides of the knives, indicating that

those rays which pass nearest the edges of the knives, have been drawn from their former direction towards the knives. This property of light is called *inflection*. The edge of any other thin plate of metal produces the same effect.

Experiment II.

If we let a beam of light pass into a dark room through a narrow slit made in a window-shutter, not above $\frac{1}{400}$ part of an inch broad, the beam of light will be split into two, and leave a dark space in the middle, it will therefore be attracted by both sides of the slit.

Experiment III.

The shadow of a small body, as a hair, a thread, &c. placed in a beam of the sun's light, will be much broader than it ought to be if the rays of light passed by these bodies in right lines, or without being attracted by them.

6. REFRACTION OF LIGHT.

When a ray of light passes through the same medium, or when it passes perpendicularly from one medium to another, it continues to move on, without changing its direction. But the case is different when it passes obliquely from one medium to another of a *different density;* it is then bent from its first direction and assumes a new one; it is said to be *refracted*. When it passes into a denser medium, it is refracted *towards* the perpendicular; but when it passes into a rarer medium, it is refracted *from* the perpendicular.

The denser the medium, the more the rays are bent, and approach to a perpendicular let fall upon its surface.

This however must always be understood of the rays which fall obliquely upon these *media*, for those rays which fall perpendicularly do not suffer any deviation; *refraction only takes place when the rays fall obliquely*, and is so much greater

as their angle of incidence is more oblique. After having taken the new direction, the ray again proceeds invariably in a straight line, till it meets with a different medium, when it is again turned out of its course. This refraction of light may be illustrated by means of the following experiments :

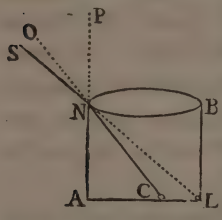
Experiment I.

Take an empty bason, and on the bottom fix marks at a small distance from each other, then take it into a dark room and let in a ray of light; where this ray falls upon the floor place the bason, so that its marked diameter may point from the window, and so that the beam of light may fall on the mark most distant from the window. Having done this when the bason is filled with water, the beam which before fell upon the most distant mark, will now by the refractive power of the water be turned out of its straight course, and will fall two, three, or more marks nearer to the centre of the bason.

This may be more clearly proved in the following manner :

Experiment II.

Let a small bright object be laid upon the bottom of a cylindrical vessel N. B. A. L. at C. so that a ray passing in a right line from the remote edge of the object to the eye at S. will be intercepted by the edge of the vessel, or that the first ray which is not intercepted passes in the direction O. N. C. above the eye. While the eye continues in the same situation, if the vessel be filled with water the object will become visible, that is the ray which passed from the remote edge of the object in a right line C. N. O. by the vessel, on entering the air is refracted into the direction N. S. towards the eye or from the perpendicular P. N. A.



SECT. III.

ANALYSIS OF LIGHT BY THE PRISM.

EVERY ray of light consists of seven parts; the first of these seven parts of the ray, excites upon our organs of sight, the sensation which we call *red*, the second excites the sensation called *orange*, the third *yellow*, the fourth *green*, the fifth *blue*, the sixth *indigo*, and the seventh *violet*.

None of these seven parts of a ray of light can be further decomposed; they always produce the same colour, on which account they are called original or primitive colours.

To prove that light consists of these primitive colours, let a ray of it fall through a hole in a window-shutter into a darkened room; and place a glass prism parallel to the horizon with its axis perpendicular, so as to receive the beam of light. On turning the prism slowly about its axis, we perceive that the refracted light on the opposite wall first descends, and then ascends; between the ascent and descent, that is where the *spectrum* is stationary, the prism is to be fixed.

The beam of light now passes into the prism, and is there refracted into its primitive rays, *viz.* the lower extremity of the *spectrum* is red, above this is placed the orange, afterwards the yellow, then the green, the blue, the indigo, and lastly the violet which is placed in the upper part of the image.

If small bodies be placed in these *spectra*, they will appear of the same colour, red in the red light, green in the green light, &c.

The decomposition effected by means of the prism has therefore been called an analysis of light.

These coloured rays differ from each other in reflexibility, refrangibility, and inflexibility. The red is the most refrangible, the violet the least; the others are refrangible in the following order, namely, orange, yellow, green, blue, indigo, and violet.

Dr. Herschel has lately proved* that the rays of light differ in their power of illuminating objects. The rays towards the middle of the spectrum possess the greatest illuminating powers, and those at the extremity, the least; the illuminating power of the rays gradually diminishes from the middle of the spectrum towards its extremities.

It has been supposed that three of these colours, the red, yellow, and blue, were simple; and that the other four were formed each of the two contiguous ones; that is, the orange from the red and yellow; the green from the yellow and blue; the indigo from the blue and violet; and the violet from the indigo and red. But this supposition has not yet been satisfactorily proved.

* Philosoph. Trans. 1800. p. 255.

SECT. IV.

THEORY OF COLOURS.

HAVING so far considered the nature and effects of light, and seen that it is subject like other matters to the laws of attraction and repulsion, and that it may be analysed by means of the prism into several rays of different tints; we shall now endeavour to prove, that from the nature of these different tints, arises that variety of shades which paints the face of nature.

Hence it is that whatever pleasure we derive from the beauty of colouring, is owing to the different refrangibility of light, each object sending back to our eyes, those rays, which the peculiar structure of its surface is best adapted to reflect: In this sense, the blushing beauties of the rose, and the modest blue of the violet, may be considered as not in the object themselves, but in the light that adorns them in those robes.

The colours of all natural bodies depend on this refrangibility of light; they may be considered as prisms, which decompose or rather divide the light. Some reflect the rays without producing any change, and these are *white*; others absorb them all and are therefore *black*; the greater or less affinity of the several rays with various bodies is no doubt the cause that when a pencil of light falls upon a body, some rays enter into it, whilst others are reflected; and it is this which affords the diversity of colours and the prodigious variety of shades under which bodies appear to our eyes: and thus are formed the pellucid stream, the green sea, the white froth, the dark pool, the azure sky, the varying colours of the pigeon's neck, the opal, the mother of pearl, the

silk called changeable, &c. and hence the white colour of the European, the copper colour of the American, and black colour of the Negro.

WHITENESS.

The most curious composition of light, is that of whiteness; there is no one sort of rays which can alone exhibit this colour, it is always compound, and to its composition all the aforesaid primary colours are necessary. It is the most surprising composition, an assemblage of all the colours of the prism, in union in a due proportion. *Whiteness therefore or the solar light, is always compound,* it is produced by a copious reflection of the rays of all sorts of colours.

A spinning-top painted on the surface with the colours of the spectrum of the prism may serve to prove this. On spinning the top, it revolves rapidly on its axis; while it is so revolving, none of the colours can possibly be distinguished singly, but the whole appears *white*; this whiteness will be greater in proportion as the primitive colours are brighter.

BLACKNESS,

On the contrary, is produced by a total absorption of the incidental light, which being stopped or absorbed in the body is not reflected outwards, but refracted within, hence it is lost and produces darkness.

Such are the principal physical properties of light. Optical writers may be consulted for a great number of curious and useful deductions made from these principles and applied to the doctrine of vision, the nature of colours, the construction of mirrors, and other instruments, not immediately within the province of chemistry.

SECT. V.

CHEMICAL PROPERTIES OF LIGHT.

THE chemical effects of light have much engaged the attention of philosophers. Its influence upon animal, vegetable and other substances shall form the subject of the following heads.

1. EFFECTS OF LIGHT ON VEGETABLES.

Every body knows that most of the discous flowers follow the sun in his course; that they attend him to his evening retreat, and meet his rising lustre in the morning with the same unerring law. It is also well known that the change of position in the leaves of plants at different periods of the day is entirely owing to the agency of light, and that plants which grow in windows in the inside of houses are as it were solicitous, to turn their leaves towards the light. Natural philosophers have long been aware of the influence of light on vegetation. It was first observed that plants growing in the shade, or darkness, are pale and without colour. The term *etiolation* has been given to this phenomenon, and the plants, in which it takes place, are said to be *etiolated* or *blanched*. Gardeners avail themselves of the knowledge of this fact, to furnish our tables with white and tender vegetables. When the plants have attained a certain height, they compress the leaves, by tying them together, and by these means (or by laying earth over them) deprive them of the contact of light: and thus it is that our white celery, lettuce, cabbages, endive, &c. are obtained. For the same reason wood is white under the the green bark; roots are less coloured than plants, some of them alter their taste, &c. they even acquire a deleterious

quality when suffered to grow exposed to light. Potatoes are of this kind. Herbs that grow beneath stones or in places utterly dark, are white, soft, aqueous and of a mild and insipid taste. The more plants are exposed to the light, the *more colour* they acquire. Though plants are capable of being nourished exceedingly well in perfect obscurity, and in that state they even grow much more rapidly than in the sun, (provided the air that surrounds them is fit for vegetation,) they are colourless, and unfit for use.

Professor Davy* found by experiment that red rose-trees carefully excluded from light, produce roses almost white. He likewise ascertained that this flower owes its colour to light entering into its composition, that pink, orange and yellow flowers imbibe a smaller proportion of light than red ones, and that white flowers contain no light.

But vegetables are not only indebted to the light for their colour: taste and odour are likewise derived from the same source.

Light contributes greatly to the maturity of fruits and seeds. This seems to be the cause why under the burning sun of Africa vegetables are in general more odoriferous, of a stronger taste, and more abounding with resin. From the same cause it happens that hot climates seem to be the native countries of perfumes, odoriferous fruits, and aromatic resins.

The action of light is so powerful on the organism of vegetables, as to cause them to pour forth torrents of pure air from the surface of their leaves into the atmosphere, while exposed to the sun; whereas on the contrary, when in the shade, they emit an air of a noxious quality.

* Beddoes's Physic. and Medic. Contrib. p. 790.

Experiment I.

Take a few handfuls of fresh gathered leaves of mint, cabbage or any other plant; place them in a bell-glass filled with fresh water, and invert it into a bason with the same fluid. If the whole be then exposed to the direct rays of the sun, small air bubbles will appear on the surface of the leaves which will gradually grow larger and at last detach themselves and become collected at the surface of the water. This is oxigen gas, formerly called vital air.

All plants do not emit this air with the same facility; there are some which yield it the moment the sun acts upon them, as the leaves of the jacobœa or ragwort, of lavender, peppermint and some other aromatic plants. The leaves afford more air when attached to the plant, than when gathered; the quantity is also greater, the fresher and sounder they are; and if full grown and collected during dry weather. Green plants afford more air than those which are of a yellowish or white colour. Green fruits afford likewise oxigen gas; but it is not so plentifully furnished by those which are ripe. Flowers in general render the air noxious. The nasturtium indicum, in the space of a few hours, gives out more air than is equal to the bulk of all its leaves.

On the contrary, if a like bell-glass, prepared in the same manner, be kept in the dark, another kind of air will be disengaged of an opposite quality. The method of collecting and examining these gases, will be shown hereafter, and the philosophy of their production will then be more fully pointed out.

There is not a substance, which in well closed glass vessels and exposed to the suns's light does not experience some alteration.

Camphor kept in glass bottles exposed to light, chrystallises or vegetates into the most beautiful symetrical figures, on that side of the glass which is exposed to the light.

Yellow wax exposed to the light loses its colour and becomes bleached. Gum guaiacum reduced to powder, becomes green on exposure to light. Vegetable colours, such as those of saffron, logwood, &c. become pale or white, &c.

2. EFFECTS OF LIGHT ON ANIMALS.

The human being is equally dependent on the influence of light.

Animals in general droop when deprived of light, they become unhealthy and even sometimes die. When a man has been long confined in a dark dungeon (though well aired,) his whole complexion becomes sallow, pustules filled with aqueous humours break out on his skin, and the person who has thus been deprived of light, becomes languid and frequently dropsical.

Worms, grubs, and caterpillars which live in the earth or in wood are of a whitish colour; moths and other insects of the night are likewise distinguishable from those which fly by day, by the want of brilliancy in their colour. The difference between those insects in northern and southern parts, is still more obvious.

The parts of fish which are exposed to light, as the back, fins, &c. are uniformly coloured, but the belly which is deprived of light is white in all of them.

Birds which inhabit the tropical countries have much brighter plumage, than those of the north. Those parts of the birds which are not exposed to the light are uniformly pale. The feathers on the belly of a bird are generally pale or white, the back which is exposed to the light is almost always coloured; the breast which is particularly exposed to light in most birds, is brighter than the belly.

Butterflies, and various other animals of equatorial countries, are brighter coloured, than those of the polar regions. Some of the northern animals are even darker in summer, and paler in winter.

3. EFFECTS OF LIGHT ON METALLIC OXIDS.

Experiment I.

Effect of light on muriate of silver.

Dissolve pure silver in nitric acid, and add to it muriatic acid, a decomposition will take place; for the muriatic acid having a stronger affinity to silver, than the nitric acid has, will unite to it, and fall to the bottom as an insoluble compound called muriate of silver.

Separate this muriate by pouring the whole on a filter as quick as possible and expose it still wet to the light, on a plate of white glass, on the lower side of which black paper has been pasted; at the end of some hours it will be seen that the light has exercised no action but at the surface, where the muriate will be found blackened or re-approaching to the metallic state; while at the place where the light did not fall, there will be no alteration.

Mr. T. Wedgwood has availed himself of the property which light exercises upon the metallic oxids, for copying paintings upon glass, and making profiles of figures by the mere agency of light upon nitrate of silver in the following manner:*

Experiment II.

Let white paper or leather be covered with a solution of nitrate of silver, place it behind a painting on glass, and expose it to the solar light, the rays emitted through the differently painted surfaces will produce distinct tints of brown or black, sensibly differing in intensity, according to the shades of the picture; and where the light is unaltered, the colour of the nitrate becomes deepest.

* Journals of the Royal Institution, No. 9, p. 171.

When the shadow of any figure is thrown upon the prepared surface, the part concealed by it remains white, and the other parts speedily become dark.

For copying paintings on glass, the solution should be applied on leather; and, in this case, it is more readily acted upon than when paper is used.

After the colour has been once fixed upon the leather or paper, it cannot be removed by the application of water, or water and soap, and it is in a high degree permanent.

The copy of a painting, or the profile, immediately after being taken, must be kept in an obscure place. It may indeed be examined in the shade, but, in this case, the exposure should be only for a few minutes; by the light of candles or lamps, as commonly employed, it is not sensibly affected.

No attempts that have been made to prevent the uncoloured parts of the copy or profile, from being acted upon by light have as yet been successful. They have been covered with a thin coating of fine varnish, but this has not destroyed their susceptibility of becoming coloured; and even after repeated washings, sufficient of the active part of the saline matter will still adhere to the white parts of the leather or paper, to cause them to become dark when exposed to the rays of the sun.

Besides the applications of this method of copying that have been just mentioned, there are many others. And it will be useful for making delineations of all such objects as are possessed of a texture partly opaque and partly transparent. The woody fibres of leaves, and the wings of insects, may be pretty accurately represented by means of it, and in this case, it is only necessary to cause the direct solar light to pass through them, and to receive the shadows upon prepared leather.

When the solar rays are passed through a print and thrown upon prepared paper, the unshaded parts are slowly copied; but the lights transmitted by the shaded parts, are seldom so definite as to form a distinct resemblance of them by producing different intensities of colour.

Professor Davy has found, that the images of small objects, produced by means of the solar microscope, may be copied without difficulty on prepared paper. This will probably be a useful application of the method; that it may be employed successfully however, it is necessary that the paper be placed at a small distance from the lens.

With regard to the preparation of the solution, this gentleman found the best proportions those of 1 part of nitrate to about 10 of water. In this case, the quantity of the salt applied to the leather or paper, will be sufficient to enable it to become tinged, without affecting its composition, or injuring its texture.

Count Rumford has made some valuable experiments concerning the chemical properties that have been attributed to light.* This philosopher observed, that white ribbons wetted in a diluted aqueous solution of nitro-muriate of gold, and exposed wet to the action of the sun's direct rays, soon become tinged of a beautiful crimson colour. Magnesia wetted with a solution of nitro-muriate of gold, and exposed wet to the action of the sun's rays, soon changes to a purple, and afterwards to a deep crimson colour. But if the ribbon or magnesia after being so wetted, be dried in a dark place, and then exposed in a dry state to the sun's rays, their colour will not be sensibly changed by the action of the light.

The following method of silvering ivory, which we shall transcribe from the Count's paper† is extremely beautiful and may become a valuable acquisition to the arts.

Experiment II.

Take a slip of ivory, immerse it in a diluted solution of pure nitrate of silver, and suffer it to be immersed, till the ivory has acquired a bright yellow colour; then take it out of

* Rumford's Philoſoph. Papers, vol. I. 1802, p. 22.

† l. c. p. 363.

the solution, and immerse it in a tumbler of pure water, and immediately expose it in the water, to the direct rays of a bright sun. After the ivory has been thus exposed for about two or three hours to the action of the sun's light, it will appear black, but on rubbing it a little, the black surface will become changed into a metallic one, resembling a slip of fine silver.

Although this coating of revived metal, is extremely thin, yet if the ivory be well impregnated with the nitrate of silver, the solution will penetrate to a considerable depth, and as fast as the silver wears off from the surface of the ivory, the oxid below it becoming uncovered, and exposed to the light, a new coating of revived metal will be formed to replace it, and the surface of the ivory will not lose its metallic appearance.

The Count further observes, that this method of silvering ivory, which is not only expeditious, but very economical, might no doubt be employed with advantage in many cases, for ornamental purposes. The process is certainly curious and beautiful when considered merely as a philosophical experiment.

All metallic oxids, but especially those of mercury, bismuth, lead, silver and gold, become of a deeper colour, by exposure to the sun; some of them become perfectly revived, others only partially, as may be seen by observing various painter's colours, preserved in powder, and exposed to the light, in the windows of colour shops. The yellow oxid of mercury, the acetate and sweet muriate, are very soon affected by light.

The black oxid of mercury, obtained by pouring ammonia copiously into a neutral solution of sulphate of mercury, (or rather on dry sulphate) exposed to the rays of light, becomes readily converted into fluid quicksilver.

The yellow oxid of tungsten, if exposed to light, loses weight and becomes blue.

Green prussiate of iron exposed to the solar light becomes also blue.

The rose-coloured solution of sulphate of manganese becomes colourless when kept exposed to the light, and regains its colour when removed into the dark.

4. EFFECTS OF LIGHT ON ACIDS.

Experiment I.

Decomposition of nitric acid by light.

If a white glass bottle be half filled with concentrated nitric acid, and exposed to the rays of the sun, at the end of some days the white acid will be converted into an orange coloured and fuming one, and the bottle will become filled with red vapours. If the bottle be now carried into a dark place and suffered to remain there for some time, the red vapours will gradually diminish, and the acid return to its primitive or colourless state.

Nitric acid as we shall see hereafter consists of the basis of two æriform fluids, called nitrogen and oxigen. The acid in this instance loses part of its oxigen, which unites with the light and forms oxigen gas; hence the acid becomes more volatile, and fuming.

This experiment succeeds best with highly concentrated acid, exposed to the light in bottles only half filled.

If oxigenated muriatic acid be exposed to the light, oxigen gas may easily be obtained, in the following manner, in considerable quantity.

Experiment II.

Decomposition of oxigenated muriatic acid by light.

Put concentrated oxigenated muriatic acid into a bottle and fit to it a bent glass tube, one end of which pierces the cork of the bottle, and the other end reaches under a bell or receiver,

filled with and inverted in a bason of water, care being taken that the tube does not touch the acid; the light falling directly on the acid, decomposes it, and a part of the oxigen of the acid becomes disengaged in the gazeous form, and passes into the receiver.

Thus there remains no doubt that light acts chemically on various substances. We have seen that incombustible bodies, such as oxids of metals, become combustible when exposed to the light; that acids are decomposed by its contact; that various other substances change their nature; that vegetables acquire colour, odour, taste and inflammability, whereas on the contrary deprived of light, they remain pale and insipid, and are what is called *etiolated* or blanched.

Light therefore enters into the composition of bodies, and its effects are so considerable, that the skilful operator ought to be constantly aware of the influence it may have upon the products submitted to his investigation.

SECT. VI.

COMBINATION OF LIGHT WITH DIFFERENT BODIES.

PHILOSOPHERS have ascertained that various bodies, if exposed to light, either at a high or low temperature, combine with it and emit it again, without alteration, under certain circumstances.

Substances of this kind have been called

SOLAR PHOSPHORI,

Or substances which shine in the dark without emitting heat, after having been exposed to the light.

The world is stocked with an immense variety of bodies of this kind. All terrestrial objects not only possess a power of absorbing light, but they likewise emit it again. The eyes of cats, owls, and several other animals, are constructed so as to collect light, to enable them to find their food in the dark. Water condensed into the form of ice or snow emits light remarkably. This accounts for the light afforded by snow, even when the heavens are involved in extreme darkness. The snow on the ground absorbs light, by being exposed to it all the day, and emits a considerable quantity again in the dark.

The principal bodies of this kind are the following:

1. SULPHURET OF BARYTES,

OR

BOLOGNIAN PHOSPHORUS.

The process for preparing this phosphorus is as follows: pieces of sulphate of barytes are first made red-hot, for a few minutes, in a covered crucible, placed in the middle of a fire, and then left to cool. When cold they are pulverized in a stone mortar, and sifted. This powder is formed into a paste with a little mucilage of gum arabic, and divided into cakes, cylinders, or pieces of the thickness of a quarter of an inch. Those pieces are dried in a moderate heat, and then exposed, by degrees, to a more violent heat, among charcoal, in a strong drawing wind-furnace. As soon as the coals are half consumed, the furnace must be filled a second time, and the phosphorus be left undisturbed. When the coals are quite consumed the ashes must be carefully blown off with a pair of bellows, and the phosphorus is found at the bottom of the grate.

These phosphoric stones exposed for a few minutes to the light, shine when taken into the dark like burning coals. Even immersed in water, they emit the same glowing light. Not only this phosphorus, but likewise all other phosphori of this class, lose their luminous property gradually, which they however regain on being heated a second time.

RATIONALE....During the process of preparing the Bolognian phosphorus a partial decomposition of the sulphuric acid of the sulphate of barytes takes place. The ignited charcoal, at a high temperature, has a greater affinity to the oxigen of the sulphuric acid than the sulphur has, it therefore attracts it, and forms carbonic acid gas; part of the sulphur of the sulphuric acid becomes thus separated; it unites to the pure barytes, and forms sulphuret of barytes, which seems in this union more disposed to decompose oxigen gas, than when single. The

phenomenon is therefore to be considered analogous to a slow combustion of the sulphur; the extrication of caloric, during each instant of observation, being too inconsiderable to be appreciable either by the senses or by the thermometer.

2. SULPHURET OF LIME,

OR

CANTON's PHOSPHORUS.

To prepare this phosphorus, take some oyster shells, calcine them, by keeping them in a good coal-fire, for about an hour. Then let the purest part of the lime so obtained, be pulverized and sifted. To three parts of this powder, add one of flowers of sulphur, mix them well together, put the whole into a crucible, and ram it tightly. Let it then be placed in the middle of a fire, where it must be kept red hot for an hour at least, it may then be removed to cool. When it is cold cut or break the mass to pieces. Scrape off the brightest part, which if good, will shine in the dark. This is to be kept in a glass phial, hermetically sealed.

This is Canton's phosphorus. The quantity of light which a little of it gives, when brought into a dark room, after it has been exposed for a few minutes to the sun, or even day-light is sufficient to shew the hour by a watch, if the eyes have been previously kept shut a minute or two.

RATIONALE...Analogous to the former.

3. NITRATE OF LIME,

OR

BALDWIN's PHOSPHORUS

Is a combination of nitric acid, with lime, obtained by dissolving carbonate of lime in nitric acid; and evaporating the solution in an earthen vessel to dryness. This solid salt

is then to be rammed into a crucible, which is placed in the middle of a good fire, where it is to be kept, till the whole mass becomes liquid. As soon as the mass has fused about eight minutes, the crucible is to be removed, and its contents poured out into an iron pot, previously heated. This mass when still hot, is to be preserved from the contact of the air in a well stopped phial.

Baldwin's phosphorus when well prepared, shines with a beautiful white light, after having been exposed to the sun for a few hours.

Modern observations have made us acquainted with several other bodies which possess the property of shining, after having been exposed to an elevated temperature. We know that, not only all neutral salts with a base of barytes belong to this class; but also many other substances, namely, diamonds, and several precious gems, magnesia, carbonate of magnesia, sulphate and carbonate of lime, aluminous earth, sulphate of potash, sulphate of strontian, some metallic oxids, cotton wool, appatite, zeolite, &c. display the same phenomena.

The combination of fluoric acid with lime, commonly called fluor spar or fluate of lime, is remarkable on account of its property of shining in the dark, at an elevated temperature only. When the phosphoric flour spar is reduced to a fine powder, and placed in contact with any body, heated to about 212° Fahr. though not ignited, and afterwards taken into a dark place, it shines with a phosphoric light. By this means may be performed writings, drawings, &c. upon an iron or copper plate, with a thin mucilage of gum arabic or with white of egg and strewing over it some fine powdered fluate of lime. When this is dry, all the superfluous powder must be carefully blown off and the plate removed over a gentle coal fire. As soon as it is heated the delineated objects become luminous, and opake again when the plate becomes cold.

Not only a great variety of mountain crystals, lapis lazuli, several kinds of stones, &c. become luminous in a high temperature, but also Dr. Marum observed, that a phosphoric light is discernable in expressed oils and animal fats, when heated to 450° Fahr.

PHOSPHORIC SUBSTANCES WHICH BECOME LUMINOUS BY ATTRITION OR PERCUSSION.

The most celebrated and most anciently known body of this kind is called

MURIATE OF LIME,
OR
HOMBERG's PHOSPHORUS.

Homberg's process for obtaining this phosphorus, is as follows: One part of powdered muriate of ammonia is mixed with two of powdered lime, introduced into a red hot crucible, and keep hot till the mixture becomes liquid. As soon as the mass has been fused for a few minutes it is poured out, into a heated iron pot, broken into pieces, and preserved in a well stopped phial.

This substance has the property of emitting a phosphoric light, when struck or excited with a hard sharp body in the dark. When a red hot poker is dipped into the fused substance, and rubbed after it is cool with another piece of metal, it becomes luminous, and gives out phosphoric sparks and light.

This phosphorus is obtained more conveniently as well as at less expence, when that portion of muriate of lime, which remains in the retort, after the decomposition of muriate ammonia by lime is melted and then exposed for some minutes to such a degree of heat, as is sufficient to melt the surface of a

green glass matrass; it acquires the property of giving fire with steel, and emits phosphoric sparks and flashes of light in a high degree.

Those kind of phosphori or substances which give a perceptible sparkling light by attrition or percussion, without having been exposed either to the solar light or fire, are likewise numerous. Flints, and several other siliceous stones, struck against one another, appear luminous in the dark, some through the whole mass, others only on the side struck upon. Tremolit, phosphate of lime, black-jack, and other stones of this genus, become luminous or yield phosphoric light in the dark, when struck with a sharp instrument. Gum elemi, various resins, and sugar, emit a perceptible light by attrition or percussion, without having been exposed to light or heat.

Mr. T. Wedgwood* has published an excellent paper on the light produced by attrition.

Mr. Coates† of Clifton observed, that if two pieces of bonnet-cane were rubbed together in the dark, light was liberated. Professor Davy who pursued this experiment found that all canes of this kind when briskly rubbed together produce sparks of white light, which are more vivid on collision.

But the most perfect phosphorus of this class, is supersaturated borate of soda. Two pieces of this salt struck one against another, or a swift blow with any sharp instrument upon it, produces such a flash of white light, as none of the before-mentioned substances are capable of giving.

Other substances again emit light on immersion into acids.

Mr. Westrumb‡ observed that when fresh decarbonated magnesia, is thrown into concentrated sulphuric, acid light is liberated which produces an appearance similar to that known by the name of red heat.

* Philosoph. Trans. 1792. † Nicholson's Journal, May, 1799, p. 56.
‡ Crell's Chemic. Annals, 1784, p. 432.

Experiment I.

To perform this experiment about two scruples or one drachm of magnesia recently freed from carbonic acid by heat must be put into a tea-cup, and half an ounce of highly concentrated sulphuric acid poured over it at once, so as to cover the magnesia. A prodigious quantity of vapour is instantly extricated, sparks are thrown about, and the mixture becomes ignited. Mr. Westrumb observed, that coloured (or partly deoxigenated) sulphuric acid answered the purpose better, than when the acid was colourless.

During the combination of lime with muriatic acid, and of dry caustic potash or soda with sulphuric acid, a white light is uniformly perceived.

Various animal and vegetable substances, likewise emit light under peculiar conditions only. Fish, and several other marine animals, both in a living state, and when dead, possess this property; as instances of the first may be mentioned the shell-fish called *pholas*, the *medusa* phosphorea, and various other *molluscæ*.

In the class of insects are many which emit light very copiously, particulary several species of *fulgora* or lantern fly, and of *lampyris* or glow-worm; also the *scolopendra electrica*, and a species of crab, called *cancer fulgens*.

Rotten wood is well known to emit light spontaneously. Peat earth has also the same property.

The flesh of quadrupeds has also been observed to emit light.

The softest parts become often totally phosphoric, it appears in this state, as if sprinkled over with gems. Upon touching the brilliant luminous particles they come off, and appear almost liquid.

The medullary substance of the brain of human beings or rather the nervous system in general is said to possess this property in a high degree; it is this particularly which gives rise to those phosphorescent lights frequently observed in anatomical theatres

Citizen Cabarris, who read a memoir on this subject before the national institute, remarks that a variety of observations have made him conclude, that the quantity of phosphorescent matter after death, bears some proportion to the activity of the nervous system during life.

Dr. Hulme has made some interesting experiments on the light which is spontaneously emitted from various bodies. He believes (as is highly probable) that the light is a constituent part of many animals, particularly of the marine fishes, that it may be separated, collected, and rendered permanent for some time by peculiar processes, for which we refer our reader to the interesting, curious, and well conducted experiments enumerated in paper.*

PHOTOMETER.

In order to measure the relative intensity of light emitted by luminous bodies, various kinds of contrivances called PHOTOMETERS have been contrived. The most perfect instrument of that kind, is the photometer invented by Count Rumford. By means of this instrument, the Count has made a series of interesting experiments, in order to determine the quantities of light produced by lamps and candles of different kinds, and the relative expense of lighting rooms in various ways. The Count found that the saving in the quantity of oil consumed, by an Argand's lamp, compared with one of the common construction with a ribbon wick, amounted to about 15 *per cent.* in the production of an equal quantity of light. He also ascertained, that an Argand's lamp of the common size well trimmed, and burning with its greatest brilliancy, emitted about as much light as 10 common wax candles, each $\frac{3}{4}$ of an inch in diameter; and that the light

* Philosoph. Trans. 1800, p. 161.

of a good wax candle varies from 100 to about 60; if namely such a candle when newly snuffed, and burning with its greatest brilliancy, emits a quantity of light = 100, its light will be reduced to 20, and even as low as 16, when it is suffered to burn very dim for want of being snuffed. The loss of light emitted by a tallow candle under similar circumstances, was found to be much greater. A particular account of the principles on which Count Rumford's photometer is founded, together with some masterly drawings of the instrument, which performs with the utmost facility not only all the ingenious experiments of Bouguer, Lambert, and Leslie, but many others, equally satisfactory, may be found in Count Rumford's work* from which these *data* have been copied.

Thus far we have examined the two imponderable substances diffused through space, namely caloric and light. They have been considered by different philosophers as substances whose particles mutually repel each other, for they are never found cohering together.

They agree in many of their properties; they radiate from hot or luminous bodies with inconceivable velocity; they are transmitted, reflected, and refracted by different substances; while they have the property of combining with others.

CALORIC we have seen is the cause of the sensation of heat, it produces expansion, is the cause of fluidity, &c.

LIGHT on the other hand, produces the sensation of vision, and is the cause of colours. Both substances do not affect the ponderability of bodies, all attempts to weigh them have hitherto been in vain; they have therefore been called IMPONDERABLE SUBSTANCES, if they are absolutely *imponderous* is left to the determination of the more successful labours of future enquirers.

* Rumford's Philosophical Papers, 1802, p. 270.

SUBSTANCES NOT YET PRODUCIBLE BY ART, BUT ANALOGICALLY CONSIDERED AS SIMPLE.

PART X.

SECT. I.

OXIGEN.

THIS substance although existing sometimes in a solid, and sometimes in an aeriform state, is never distinctly perceptible to the human senses, but in combination.

We know it only in its combination, by its effects. Nature never presents it solitary; chemists do not know how to insulate it. It is a principle which was long unknown. It is absorbable by combustible bodies, and converts them into acids. It is an indispensible condition of combustion, uniting itself always to bodies which burn, augmenting their weight, and changing their properties. It may be disengaged in the state of oxigen gas, from burnt bodies, by a joint accumulation of caloric and light. It is highly necessary for the respiration of animals. It exists universally dispersed through nature and is a constituent part of atmospheric air, of water, of acids, and of all bodies of the animal and vegetable kingdoms.

One of the most remarkable combinations into which it is capable of entering, is that which it forms with light and caloric. The nature of that mysterious union has not been ascertained, but it is certain that in that state it constitutes the gazeous fluid called OXIGEN GAS, which it will be more proper to consider hereafter.

SECT. II.

HIDROGEN.

HIDROGEN is a substance not perceptible to our sensations in a separate state; but its existence is not at all the less certain. Though we cannot exhibit it experimentally uncombined, we can pursue it, while it passes out of one combination into another; we cannot indeed arrest it on its passage; but we never fail to discover it, at least if we use the proper chemical means, when it presents itself to our notice in a new compound.

Hidrogen, as its name expresses, is one of the constituent elements of water. Its existence was unknown till lately. It is plentifully distributed in nature, and acts a very considerable part in the processes of the animal and vegetable economy. It is one of the ingredients in the mixtures of bitumen, of oils, fats, ardent spirit, ether, and in fact of all the proximate component parts of all animal and vegetable bodies. It forms a constituent part of all animal and vegetable acids. It is one of the bases of ammonia and of various other compound gases.

It possesses so great an affinity with caloric, that it can only exist in the state of gas, it is consequently impossible to procure it in the concrete or liquid state, independent of combination.

Solid hidrogen, therefore, united to caloric and light forms HIDROGEN GAS, which will be noticed in its proper place.

SECT. III.

NITROGEN.

NITROGEN or Azote is another simple body very abundant in nature though not producible alone or in an insulated state.... It is not distinctly perceptible to the human senses, however aided by instruments. We know it only in its combination. But the reality of its existence is unquestionable; since we can mark its passage out of one combination into another; since we know the laws of chemical attraction to which it is subject; since we discern the precise character of those simple substances with which it is combinable, and can distinguish the nature of the new compounds which the combination produces. The separate existence and peculiar nature of this substance were first discovered by Dr. Rutherford. It is the radical principle of our atmospheric air, and other gazeous substances, and forms a constituent part of animal and vegetable substances. It is a component part of the nitric acid, and of ammonia. It probably enters into the formation of alcalies, and it may be considered as a real alcaligen or alcalizing principle, in opposition to oxigen, which, as we have noticed before is the principle of acidity. One of the most remarkable combinations into which nitrogen is known to enter, is that which takes place between it and light and caloric. The compound thus produced is called NITROGEN GAS, which shall be treated of in a farther part of this work.

We have noticed these three substances here separately, because they act so very important a part in all the phenomena of chemistry, that it is requisite to have some previous notion of them before we proceed any farther. They shall be more circumstantially described hereafter, together with the rest of the bodies enumerated before in the table of simple substances.

COMBUSTIBLE BODIES, DESTITUTE OF METALLIC PROPERTIES.

SULPHUR.

PART XI.

SECT. I.

NATURAL HISTORY OF SULPHUR.

SULPHUR which is also known by the name of brimstone, is the only simple combustible substance which nature offers pure and in abundance. It was the first known of all. It is found in the earth, and exists externally in depositions, in sublimed incrustations, and on the surface of certain waters, principally near burning volcanos. It is found combined with many metals. It exists in vegetable substances, and has lately been discovered by Mr. Carlisle in the albumen of eggs.*

Sulphur in the mineral kingdom is either in a loose powder, or compact; and then either detached or in veins. It is found in the greatest plenty in the neighbourhood of volcanos or pseudo-volcanos, whether modern or extinct as at *Solfatara*, &c. and is deposited as a crust on stones contiguous to them, either crystallized or amorphous. It is frequently met with in mineral

* Nicholson's Journal, August, 1801, p. 178.

waters, and in caverns adjacent to volcanos; sometimes also in coal-mines. It is found in combination with most of the metals. When united to iron it forms the mineral, called *martial pyrites*, or *sulphur pyrites*. All the ores known by the name of *pyrites* of which there are a vast variety, are combinations of sulphur with different metals; and hence the names of copper, tin, arsenical, &c. pyrites. It exists likewise in combination with alumine and lime; it then constitutes different kinds of schistus, or alum ores.

PHYSICAL PROPERTIES OF SULPHUR.

Sulphur is a combustible, dry, and exceedingly brittle body, of a pale lemon-yellow colour. Its specific gravity is 1.990. It is destitute of odour, except when rubbed or heated. It is of a peculiar faint taste. It frequently crystallizes in entire or truncated octahedra, or in needles. If a piece of sulphur of a considerable size, be very gently heated; as for example, by holding it in the hand and squeezing it firmly; it breaks to pieces with a crackling noise. It is a non-conductor of electricity, and hence it becomes electric by friction. When heated, it first softens before it melts, and its fusion commences at 184° Fahr.; at 289° it becomes volatilized, and takes fire at 302°. In the beginning of fusion it is very fluid, but by continuing the heat it grows tough, and its colour changes to a reddish brown. If in this condition it be poured into water, it remains as soft as wax, and yields to any impression. In time however it hardens again and recovers its former consistence.

It unites with most of the earths and with all alcalies, and becomes soluble, when thus combined, in water. It unites to most of the metals and renders them brittle and fusible. It is soluble in oils; water takes up a minute quantity, as does ardent spirit by means of heat. It dissolves in hidrogen gas. It does not combine with charcoal, but unites to phosphorus by fusion.

Sulphur like all combustible bodies burns in proportion to the quantity of oxigen which combines with it.

If melted sulphur be exposed in the open air, to an increase of heat, it takes fire and burns with a blue flame and suffocating vapour. The result of this combustion is sulphureous acid. According to the slow or rapid combustion, it absorbs different quantities of oxigen, and the produced acid differs in its properties. Sulphur heated in a close vessel, sublimes without alteration. It is not changed by exposure to air. It is attacked by the nitric acid when poured on it in its fused state.

METHOD OF OBTAINING SULPHUR.

A prodigious quantity of sulphur is obtained from Solfatara in Italy. This volcanic country every where exhibits marks of the agency of subterraneous fires; almost all the ground is bare, and white; and is every where sensibly warmer than the atmosphere, in the greatest heat of summer; so that the feet of persons walking there are burnt through their shoes. It is impossible not to observe the sulphur, for a sulphureous vapour which rises through different apertures is every where perceptible, and gives reason to believe that there is a subterraneous fire underneath from which that vapour proceeds.

From pyrites sulphur is extracted in the large way by the following process:

Pyrites is broken into small pieces, and put into large earthen tubes which are exposed to the heat of a furnace. A square vessel of cast-iron, containing water, is connected as a receiver with the tube in the furnace. The action of the fire proceeds, and the sulphur being thus melted is gradually accumulated on the water in the receiver. It is then removed from this receiver, and melted in large iron ladles; in consequence of which, the earthy parts with which it was contaminated are made to subside to the bottom of the ladle, leaving the purified sulphur above. It is then again melted and suffered to cool gradually, in order

to free it from the rest of the impurities. It is then tolerably pure, and constitutes the sulphur we meet with in large masses or lumps in the market.

In order to form it into rolls, it is again melted and poured into cylindrical wooden moulds, in these it takes the form in which we usually see it in commerce, as roll sulphur.

Flowers of sulphur as they are called, are formed by subliming purified sulphur with a gentle heat in close rooms, where the sublimed sulphur is collected, though the article met with in general under that name is nothing but sulphur finely powdered.

METHOD OF PURIFYING SULPHUR.

Take one part of flowers of sulphur, boil it in twenty parts of distilled water in a glass vessel for about a quarter of an hour; let the sulphur subside, decant the water, and then wash the sulphur repeatedly in distilled water: having done this, pour over it three parts of pure nitro-muriatic acid, diluted with one part of distilled water, boil it again in a glass vessel for about a quarter of an hour, decant the acid, and wash the sulphur in distilled water till the fluid passes tasteless, or till it does not change the blue colour of tincture of cabbage, or litmus. The sulphur thus carefully treated is PURE SULPHUR fit for philosophical experiments.

We shall now endeavour to prove some of the before stated properties of sulphur.

SECT. II.

EXPERIMENTAL PROOFS

OF

THE PROPERTIES OF SULPHUR.

EXPERIMENT I.

Slow combustion of sulphur.

PUT some threads previously dipped in sulphur into a cup or other vessel floating on water. Set fire to the threads and cover the whole with an inverted glass receiver. The threads will continue to burn for some time, and the whole receiver will become filled with a dense white vapour. The water will ascend into the receiver. The whole is then to be left till the vessel is become again transparent. If the water be now examined, it will have a suffocating odour and taste. It will turn the blue colour of litmus paper red and exhibit all the other signs that an acid has been formed.

RATIONALE...The sulphur being a simple body, has at an elevated temperature a great affinity to oxigen, it therefore attracts it from the atmospheric air and thus becomes converted, by slow combustion, into sulphureous acid gas, which is absorbed by water. The volume of air within the receiver being diminished is the cause of the ascent of the fluid.

This experiment may perhaps be more conveniently performed by covering burning sulphur contained in a crucible, with a large receiver and then placing the apparatus in a broad dish and surrounding it with water.

Experiment II.

Rapid combustion of sulphur.

Take a large receiver or any other round bellied bottle with a wide orifice, containing a little water, fit a bung to close it, and fasten to this bung an iron or rather earthen-ware spoon, containing a mixture of one part of nitrate of potash and six of sulphur blended together. Set fire to the mixture and introduce it expeditiously into the vessel, taking care to close the mouth accurately. In this case, the combustion will go on very rapidly, and the water at the bottom of the vessel will become sour, but without possessing much suffocating odour.

Rationale...In this experiment the combustion is not slow, but on the contrary very rapid; for the nitric acid of the nitrate of potash is decomposed, and furnishes oxigen gas, into which the sulphur is plunged the instant of its inflammation. It therefore absorbs a much greater quantity of oxigen and furnishes *sulphuric acid*, different in properties from the former, which is not completely oxigenated, and therefore is pungent and volatile.

Experiment III.

Sulphur is soluble in ardent spirit only in a state of extreme comminution.

If a piece of sulphur be left in contact with ardent spirit for any length of time, the spirit will not act upon it; but if we present the sulphur in its smallest division to the spirit, an union will then take place.

To perform this experiment, put pounded sulphur into a matrass furnished with an alembic; suspend within it a cup or

wide-mouthed bottle containing strong ardent spirit, then put on the alembic and adjust a phial to the beak; lute well the joinings, and heat the lamp.

The sulphur and spirit will now meet in a state of vapour, and the fluid which distils over, will contain sulphur in solution.

To prove that sulphur is dissolved in the spirit, water may be added; the spirit will unite to the water, and the sulphur be precipitated.

This furnishes an instance that chemical attraction takes place only between the minutest parts of bodies. (See page 46.)

Experiment IV.

Action of caloric on sulphur.

If sulphur be put in a crucible placed among burning coals, it will soon enter into fusion. This first fusion is liquid, but if it be kept longer over the fire it becomes tenacious and very thick. When poured into water in this state, it will be as soft as wax, and may be easily worked into any form between the fingers, instead of being solid or brittle as sulphur is in common. Sulphur in this state may be employed with advantage as a paste for taking impressions from seals and engraved stones.

It is this property of sulphur of which Mr. Tassie has availed himself to furnish elegant impressions of antique gems.

If melted sulphur be withdrawn from the fire as soon as it is completely melted, and left to cool slowly, its parts assume a regular symmetrical arrangement, disposed in needles, which form a crystallization of sulphur.

If the vessel in which the sulphur is kept melting, be covered with another vessel, and the air be excluded by luting, flowers of sulphur will be obtained in the upper vessel.

COMBINATION OF SULPHUR WITH METALS.

Sulphur and iron have a great attraction to each other; the iron becomes of easy fusion and brittle by this union.

Experiment I.

Formation of sulphuret of iron.

If a bar of iron be heated to *perfect whiteness* and then touched with a roll of sulphur, the two bodies combine and drop down together in a fluid state, forming sulphuret of iron, a compound of the same nature as the native iron pyrites.

By this method a bit of iron rolled out very thin may be *apparently* melted in the hand, by putting it when heated to whiteness, upon a thick piece of solid sulphur.

Remark...It is necessary that this experiment be performed under a chimney, or in a place where there is a current of air, to carry off the suffocating vapours.

Experiment II.

Artificial Volcano.

The following experiment affords a beautiful and curious representation in miniature of one of the grandest and most terrible phenomena in nature. For the introduction of it to modern notice, we are indebted to the accident of a man having collected some tons of a native mixture of iron and sulphur (iron pyrites) beneath an old shed; where, not sufficiently protected from rain and the moisture of the atmosphere, it soon swelled, became hot, cracked, emitted sulphureous vapours, ignited and lastly burnt with considerable violence.

The knowledge of this and one or two similar accidents, induced Lemery to imagine that those fires which are kindled in the interior parts of our globe, forcing their ways to the surface, produce earthquakes and volcanos from a similar combustion of pyrites, piled on each other, and moistened by water. He therefore made the experiment in question, in the following manner; the success of which fully answered his expectation, and has been the cause of its frequent repetition.

Take of powdered sulphur and iron filings, each about 50 pounds, or any other large quantity; mix them into a paste with water; bury it in the ground and cover it with moist earth pressed closely down upon it like a hill. The mass after some time swells, and exhales a white vapour; soon after the earth becoms hot, bursts with a discernible crackling, and emits a thick fetid odour. The heat increases gradually, the thick fumes diminish, and the vapour ceases; flames burst out of the earth, the whole takes fire, and in the space of about twenty-four hours flows out in currents greatly resembling lava.

Long as this experiment has been known, chemists were unable to explain its phenomena. It was reserved for the philosophers of the present schools, to furnish an explanation of it, which their knowledge of the constituent parts of each individual material of the composition enabled them to do in a manner equally plain and satisfactory. For instance, iron and sulphur we consider as simple substances; water a compound of oxigen and hidrogen; and atmospheric air a mixture of oxigen and nitrogen gases. By the specified mixture, these principles obtain a manifest augmentation of some qualities already possessed by them when separate, and an addition of others derived from their compound state; thus iron alone is capable of attracting and uniting with oxigen both from water and from atmospheric air; sulphur unites with the free oxigen of the air, but not with that of the water, so far indeed these combinations take place in very small and slow degrees, but in the composition they are remarkably increased and quickened, for in the space of a few hours so

much water is decomposed by the joint action of the ingredients, that the oxigen from the water (its caloric at the same time being set free) forms with the sulphur a considerable portion of sulphuric acid which by the further assistance of water, furnishing oxigen, attacks the iron. Here then are two sources of caloric and hidrogen gas (the other principle of water) which in its nascent state seizes on a portion of sulphur, and forms another new and inflammable compound called sulphurated hidrogen gas; those decompositions taking place through the whole mass occasion the heat, swelling, bursting, and discharge of clouds of sulphureous vapour. While these effects are rapidly going on, the temperature increases sufficiently to kindle a particle of sulphur, which communicating with the inflammable gases produces an explosion, occasionally repeated as fresh quantities of gas are evolved, the whole being now in a state of combustion burns as long as the sulphur or any other inflammable matter remains.

There is no doubt that the combustion of those enormous masses of bituminous pyrites, which are deposited in the bowels of the earth produce volcanos on the same principles. The decomposition and action of the constituent principles of the water upon the component parts of the pyrites fully determine all the phenomena.

Experiment III.

Accension of sulphur and metals.

The union of sulphur with copper and other metals at a low temperature is attended with some remarkable phenomena. In order to exhibit this experiment mix three parts of copper filings, and one of sulphur reduced to powder, intimately together; introduce this mixture into a glass tube or Florence flask, and heat it gradually over a lamp or coal fire. After the mixture has been heated to a certain degree, it begins to swell, and a small ignited spark becomes first visible at the bottom of the glass ves-

sel, which increases in size exhibiting a combustion more rapid than that of iron and sulphur.

A society of Dutch chemists consisting of Mess. Dieman, Pacts, Van Troostwyk, and others were the first who observed this phenomenon.

They introduced filings of copper with different proportions of sulphur into small glass phials, from which common air was excluded, being in some cases filled with carbonic acid gas, or nitrogen gas, and in others, with water or mercury.

Whenever the phial was heated under any of these circumstances, the mixture began to swell; the metal always *became red hot* and in some cases real inflammation took place, notwithstanding the exclusion of oxigen gas.

The proportions that produced most ignition or flame, were 40 parts of copper and 15 of sulphur.

Iron and sulphur inflamed like copper. The best proportion was three parts of iron and one of sulphur.

Tin and sulphur succeeded in the same proportion.

Lead and sulphur, the proportions being as 45 of the former and 15 of the latter.

Zinc and sulphur in the same proportion burned with explosion.

Mercury, bismuth, antimony, and cobalt, could not be made to inflame with sulphur.

These experiments succeed equally well in the Torricellian vacuum.

COMBINATION OF SULPHUR WITH ALCALIES.

Alcalies and sulphur have a great affinity to each other in the dry as well as in the humid way.

Experiment I.

Preparation of sulphuret of potash and soda.

If potash or soda be melted by a moderate heat, with equal parts of sulphur, in a covered crucible, a mass is obtained which after cooling exhibits a liver-brown colour. It is called *sulphuret of potash or soda* according to the alcali made use of.

This combination unites with gold both in the dry and humid way. To exhibit this, some leaf gold may be digested with heat, in a concentrated solution of sulphuret of potash.

Experiment II.

Preparation of sulphuret of ammonia.

Ammonia also combines with sulphur; sulphuret of ammonia may be obtained in the following manner:

Two parts of finely powdered lime are put into a dry retort, upon this one part of muriate of ammonia well mingled by trituration with one-third part of sulphur is poured, and the whole mingled together by shaking. The charged retort is then placed in a sand-heat, a receiver containing a little water is adopted, and the distillation carried on very slowly. The fluid which passes over on increasing the heat is *sulphuret of ammonia.* It is of a deep yellow colour, a volatile and disagreeable odour, and fumes strongly in contact with air. In order to obtain sulphuret of ammonia very fuming, the first fluid which passes over must be kept separate, for it is only this which is smoking, by reason of its containing some uncombined ammonia. In other respects its properties are like the former combinations of sulphur with alcalies. Its volatility renders it capable of restoring oxidated metals to the metallic state as may be evinced in the following

Experiment III.

Dissolve some crystallized nitrate of silver, free from excess of acid in a sufficient quantity of distilled water, dilute the solution with water, till writings performed with it on paper are invisible when dry. If this writing be exposed to the vapour of the sulphuret of ammonia, it will become visible with the brilliancy of silver.

Rationale...The sulphuret of ammonia gives out sulphurated hidrogen gas at the ordinary temperature of the atmosphere; on coming into contact with the solution of silver, the hidrogen attacks the oxigen of the silver and forms water, and the metal becomes revived, which then unites with the ammonia and sulphur in order to form a sulphurated ammoniuret of silver.

COMBINATION OF SULPHUR WITH EARTHS.

Experiment I.

Sulphuret of magnesia

Is best prepared in the following manner: One part of charcoal powder is to be mixed with six of sulphate of magnesia, the mixture is then reduced to dryness and ignited gradually.

Rationale...Sulphate of magnesia consists of sulphuric acid and magnesia; at a high temperature the sulphuric acid becomes decomposed by the charcoal which unites to its oxigen in order to be converted into carbonic acid gas, and sulphur is produced. The carbonic acid gas flies off and the sulphur unites to the magnesia.

Care must be taken not to ignite this sulphuret too much, for the sulphur seems to adhere to the magnesia very feebly.

In the same manner alumine may be united to sulphur.

PHOSPHORUS.

PART XII.

SECT. I.

NATURAL HISTORY OF PHOSPHORUS.

PHOSPHORUS is the next simple body we have to consider; it has never been found pure in nature. It is always met with united to oxigen, or in the state of phosphoric acid. In that state it exists very plentifully, and is united to different animal, vegetable, and mineral substances.

PHYSICAL PROPERTIES OF PHOSPHORUS.

Phosphorus is a flesh-coloured or yellowish semi-transparent substance, of the consistence of wax, but brittle during frost. In atmospheric air it is luminous at common temperatures without emitting heat. It has a rough disagreeable taste, and its odour resembles that of garlic. Its specific gravity is 2.033, water being 1.000. Phosphorus crystallizes in laminæ, in needles, or elongated octahedra. Exposed to the light it becomes covered with a crust which is first white, next orange and at last red.

It becomes liquid at a temperature of 99° Fahr. It takes fire spontaneously and burns rapidly in the open air at 122° Fahr. with a brilliant white flame and becomes converted into phosphoric acid. It is volatilized at 554° Fahr. It is soluble in caustic alcalies by the assistance of heat. Expressed and essential oils take up a small quantity, and are rendered luminous. Sulphuric ether, nitric ether, and ardent spirit, dissolve it sparingly in the cold. It combines with lime, strontia, barytes, sulphur, and with metals. It is soluble in hidrogen gas and decomposes nitric acid, and metallic solutions. It acts strongly and frequently like poison on living animals.

METHODS OF OBTAINING PHOSPHORUS.

For some time phosphorus was made in very inconsiderable quantities, and by a tedious and disagreeable process, consisting in evaporating considerable quantities of urine and decomposing them by various means.

The following processes now employed are more easy and expeditious.

1. GIOBERT's PROCESS.

According to this method phosphorus may be obtained very economically and without any offensive preparation. It consists in pouring a concentrated solution of nitrate of lead, by a little at a time, into a quantity of urine until no more cloudiness is produced by a further addition of the solution. The mixture is then to be diluted with soft water, and suffered to stand undisturbed; when the precipitate has fully subsided, the clear fluid is to be separated. The precipitate is then formed into a paste with charcoal powder, and the mass is to be dried gradually in an earthen pan, and submitted to distillation.

RATIONALE...The phosphoric acid of the urine, unites to the lead of the nitrate of lead, and the nitric acid joins to the am-

monia and soda of the urine, hence phosphate of lead and nitrate of soda and ammonia are formed. The former being insoluble falls to the bottom, and the latter salt remains in the super-natant fluid. On adding charcoal to the phosphate of lead, and exposing it to a high temperature, the union is again broken; the phosphoric acid becomes decomposed, its oxigen unites to the charcoal and forms carbonic acid gas, which flies off during the distillation; the phosphorus appears in its simple state, and the metal is left behind in the retort together with the super-abundant quantity of charcoal.

2. NICOLA's PROCESS.

Take a quantity of bones of adult animals, burn them to whiteness in an open fire and reduce them to a fine powder. Upon three pounds of this powder, after having been put into a matrass, there may be poured two pounds of concentrated sulphuric acid of commerce; four or five pounds of water must be afterwards added by degrees, to assist the action of the acid. During the whole process, the operator must place himself and the vessel, so that the fumes of the mixture may be blown from him. The whole is then to be left in a gently heated sand-bath for about twelve hours or more, taking care to supply the loss of water which happens by evaporation. The next day a large quantity of water must be added, the clear liquor afterwards decanted and the rest strained through a cloth or sieve. The residuary matter is to be edulcorated by repeated affusions of hot-water till it passes tasteless. The water which has been used to wash out the adhering acid is mixed with the before decanted or strained liquor, and the whole fluid is gradually evaporated in a flat earthen bason to the consistence of syrup. It is then to be mixed with an equal weight of charcoal powder and submitted to distillation in an iron or earthen retort. Instead of applying a receiver, the neck of the retort may be immersed in a bason of

water to a small depth, and the phosphorus as it comes over will fall in drops to the bottom.

RATIONALE...In this process the sulphuric acid unites with the calcareous earth of the bones, and forms sulphate of lime; and the phosphoric acid of the bones becomes disengaged, and remains dissolved in the liquor. The charcoal at an elevated temperature takes the oxigen from this acid, and carbonic acid gas is formed, and phosporus passes over.

METHOD OF PURIFYING PHOSPHORUS.

Phosphorus obtained in either manner is of a dirty blackish colour, and soiled with a certain quantity of charcoal and half burnt phosphorus, which gives it that appearance. In order to purify it, it must be put into a piece of chamois leather and closely tied up in it. The whole is then immersed in a vessel of boiling water, the phosphorus melts and may be pressed through the leather, taking care to keep it under the water.

It is better however to purify phosphorus by a second distillation.

Dr. Higgins purified it, by means of hidrogen gas.*

METHODS OF MOULDING PHOSPHORUS INTO CYLINDERS.

In order to form phosphorus into sticks, a funnel with a long neck may be used, the lower orifice of which is closed with a cork; the funnel is then to be filled with water and phosphorus put in it, and this being plunged into boiling water, the heat communicated to the funnel melts the phosphorus, which runs into the neck and acquires that form. The funnel is then removed

* Minutes of the society for philosoph. exper. &c.

into a vessel of cold water, and when it is thoroughly cooled, the cork is taken out and the phosphorus thrust out of its mould with a piece of wood and then preserved in water.

Pelletier invented another method which is as follows:

Take a few tubes of any length, the apertures of which are of such a size that they can be exactly closed with the extremity of the finger. Melt the phosphorus in boiling water, and apply to it one of the ends of the tube, while you hold the other in your mouth; make a short inspiration that the phosphorus may ascend a little way in the tube; stop the inspiration when the phosphorus has risen a sufficient height and close the extremity of the tube with the fore finger and immerse it in a bason of cold water. The phosphorus will soon become fixed and by a slight shake may be separated from the tube.

The combustibility and luminous property of phosphorus have given birth to various amusing experiments which we shall insert, for they are well calculated to evince some of its characteristic properties in a pleasing manner.

SECT. II.

EXPERIMENTAL PROOFS

OF THE

PROPERTIES OF PHOSPHORUS.

Experiment I.

Phosphorus burns at the common temperatures of the atmosphere.

LUMINOUS CHARACTERS.

THAT phosphorus burns at the usual temperature is obvious by writing with a cylinder of it upon black paper, or upon any other smooth surface. The writing will appear luminous in the dark, as if on fire; the fiery appearance vanishes by blowing on the object, but becomes visible again in a few seconds.

If the writing is performed upon the purple coloured paper of this country, the traces will appear red in the day-light after the luminous appearance has ceased.

Rationale...The phosphorus has been converted into phosphoric acid, which changes the blue vegetable colour of the paper to red, the light evinces the combustion of the phosphorus.

Remark...It is necessary to place the cylinder of phosphorus in a quill or metallic pencil case, in order that it may be removed from the hands, if it should take fire, which may happen, particularly in hot weather; a cup or bason of water should likewise be near at hand to plunge it into, to prevent accidents.

Experiment II.

Accension of phosphorus by friction.

Fold up in a piece of brown paper a few grains of phosphorus and rub it against any hard body, or between the paper itself, the phosphorus will inflame and set the paper on fire.

A few grains of phosphorus rubbed in a mortar with iron filings, take fire instantly.

Rationale...The friction applied in these experiments raises the temperature of the phosphorus, it then attracts the oxigen from the atmosphere rapidly, in order to become converted into phosphoric acid and the heat and light both of the phosphorus and oxigen gas are set free.

Remark...It is curious that written paper inflames more readily than paper which has not been written upon. Straw and wood are extremely difficult to be fired by burning phosphorus, they become only converted into charcoal; but sulphur, cotton, ardent spirit, ether, and essential oils, take fire by it readily.

Experiment III.

A phosphoric fire bottle.

Take a small thin phial, heat it gradually in a ladle full of sand, and introduce into it a few grains of phosphorus; the phial is then to be loosely stopped and left undisturbed for a few minutes: small quantities of phosphorus are thus repeatedly added until the phial is full. Another method of preparing this phosphoric bottle consists in heating a quantity of phosphorus and lime mixt together in a loosely stopped phial for about half an hour.

To use this fire-bottle, a common match or small bit of wood tipped with sulphur, is introduced into the phial, turned

round, and quickly drawn out, which causes the phosphorus to take fire as soon as it comes out of the bottle.

Phosphoric fire bottles may also be prepared by uniting one part of sulphur with eight of phosphorus; this compound is so inflammable that if a minute quantity be taken out of the bottle with a match, and rubbed upon a cork, it inflames instantly, and fires the match.

Experiment IV.

Phosphoric tapers.

Take a glass tube, about four inches long and one line wide, closed at one end. A small quantity of phosphorus is to be introduced into the tube and pushed to its extremity with an iron wire, after which a taper covered at one end with wax is put into it; the open end of the tube is then hermetically sealed, and the other, plunged into hot water. The phosphorus melts and fixes as it cools upon the taper. A line is then drawn by means of a diamond or file at one third of the tube. To use these tapers, the tube is broken at the marked line and when it is quickly drawn out, it takes fire and burns rapidly.

Experiment V.

Phosphorated ether.

If phosphorus be dissolved in rectified sulphuric ether, and poured into a decanter, at the bottom of which is a little water, a brilliant light is disengaged, which passes with a serpentine motion along the surface of the fluid. The air within the vessel becomes luminous, and remains for some time in this state.

1. If the decanter be unstopped and air blown into it, the luminous vapour disappears; but if the mixture be again agitated several luminous points are seen at its surface, the air of the de-

canter becomes again phosphorescent, and this may be renewed until the whole of the ether has been decomposed.

2. If a pen be dipped in water, and in this state be plunged into phosphorated ether, at the moment of contact of the two fluids, a sudden light spreads through the air, and very perceptible flashes are seen (in a dark place) to issue from time to time out of the mouth of the phial.

3. When a lump of fine loaf sugar is wetted with phosphorated ether, and thrown into a bason of water, the whole of the surface will be illuminated; by gently blowing it, beautiful undulations will be formed greatly resembling the fiery appearance of the sea.

All these experiments with phosphorated ether succeed best if the water be a little warm.

RATIONALE...The phosphorated ether is decomposed on coming in contact with a large quantity of water; the water unites with the ether; the phosphorus being then presented to the air burns, and exhibits the luminous appearance.

Phosphorated ether is best prepared by suffering sulphuric ether to stand for some weeks over a considerable quantity of phosphorus in a well stopped phial.

EXPERIMENT VI.

Liquid phosphorus.

When phosphorus is dissolved in oils it forms what is called liquid phosphorus. The best method of preparing it, is to boil very gently one part of phosphorus with six of oil of olives. The oil thus charged with phosphorus must be kept in a bottle well corked. It has the property of becoming luminous in the dark as soon as the phial containing it is unstopped, and opaque again when the phial is corked. This liquid may serve for

showing the hour of the night, by holding a pocket watch against the bottle when unstopped. It may likewise be used for forming luminous writings or drawings, by means of a small brush. It also may be rubbed on the face, hands, &c. to make them appear luminous, without injury.

Liquid phosphorus may likewise be prepared by triturating phosphorus in a stone mortar, with oil of cloves.

Experiment VII.

Accension of phosphorus by means of sulphuric acid and water.

Melt over a slow fire, in a cup, gallipot, or phial, containing a table spoonful of water, a small quantity of phosphorus; as soon as the water boils, pour into it double the quantity, by measure, of concentrated sulphuric acid. In a few minutes the surface of the mixture becomes filled with luminous vapours, a considerable ebullition takes place, accompanied with a hissing noise, which increases gradually, until the mixture takes fire with a smart explosion; little fire-balls and stars will be thrown out in all directions and the whole will boil very high.

Rationale...This accension of phosphorus is owing to the heat evolved by the mixture of the acid and water.

Remark...To perform this dangerous experiment with safety, the vessel containing the water and melted phosphorus should be fastened to the end of a long stick, in order that the operator may be at a sufficient distance when the explosion takes place; as it frequently happens that the vessels are dashed to pieces the moment the mixture is made, and the whole is thrown about to a considerable distance.

Experiment VIII.

A phosphoric fire-work.

Put a piece of phosphorus about the size of a large bean, into a clean Florence flask, holding it slanting that it may not break the glass, and pour upon it about six ounces of water, place the whole over a lamp and light the wick, which should be about half an inch from the flask; as soon as the water is heated, streams of fire will issue from it by starts, resembling sky-rockets, some particles will adhere to the sides of the flask and represent stars, and will frequently display brilliant rays. These appearances will continue at times till the water begins to simmer, when immediately a curious *Aurora Borealis* begins, and gradually ascends, till it collects into a pointed flame: when this has continued about half a minute blow out the flame of the lamp, and the apex of the flame will rush down, forming beautiful illuminated clouds of fire, rolling over each other for some time, which disappearing, a splendid hemisphere of stars presents itself: after waiting a minute or two, light the lamp again, and nearly the same phenomena will be displayed as from the beginning. Let a repetition of lighting and blowing out the lamp be made three or four times at least, that the stars may be increased. After the third or fourth time of blowing out the lamp, and in a few minutes after the internal surface of the flask is dry, many of the stars will shoot with great splendor from side to side, and some of them with brilliant rays; and these appearances will continue several minutes.

Rationale...Part of the phosphorus in this experiment, detaches itself from the water, and becomes dissolved in the vapour of that fluid, which on coming in contact with the atmospheric air takes fire, and accounts for the phenomena.

Experiment IX.

A luminous fluid which throws out flashes of light.

Water boiled with a little phosphorus for a few minutes, and preserved in a well corked phial, becomes luminous in the dark. Long cylinders of glass, filled two-thirds with this solution a little warmed, and then agitated, discharge flashes of light in all directions into the air.

Rationale...Part of the phosphorus is dissolved by the water, and remains in combination with it so long as this fluid is at rest, but becomes disengaged when the water is agitated, it then burns, and exhibits the luminous appearance.

Experiment X.

Phosphorated mercury

May be prepared by dissolving phosphorus by trituration in a mortar in as little oil of cloves as possible, and then uniting this mixture to mercury, by a continual agitation.

Long cylinders filled with this compound become luminous when shaken in the dark.

Rationale...A simple spontaneous combustion of minutely divided phosphorus.

Experiment XI.

Phosphoret of lime.

Take an earthen or glass tube, a foot long, and half an inch in diameter, closed at one end; put into this tube about half an ounce of phosphorus, cut into small pieces, and dried from

adhering water; then fill the tube with small bits of fresh burnt lime of the size of split peas; stop the opening of the tube loosely with a chalk stopper, to prevent the access of air; then heat to redness *that part of the tube which contains the lime,* by means of charcoal; when the lime may be supposed to be ignited, apply heat to the part containing the phosphorus, so as to sublime it, and to bring the vapour of it into contact with the heated lime. The lime and phosphorus will unite and form a mixture of a reddish-brown colour, which is phosphoret of lime. This preparation has the property of making fire rise out of water, when a small bit is dropt into it.

RATIONALE....The phenomena is owing to a decomposition of water, at the common temperature, which shall be more fully treated on under the article, *phosphorated hidrogen gas.*

REMARK....If a glass tube be made use of for preparing phosphoret of lime, that part of the tube which is heated (which may conveniently be done by passing it through a perforated crucible or chafing-dish, filled with ignited charcoal) should be coated with clay, or loam, in order to secure it from breaking during the process.

DIAMOND,

OR

PURE CARBON.

PART XIII.

SECT. I.

NATURAL HISTORY OF DIAMOND.

THE diamond, which was well known to the ancients, is principally found in the western peninsula of India, on the coast of Coromandel, in the kingdoms of Golconda and Visapour, in the island of Borneo, and in the Brazils.

They are generally found bedded in yellow ochre, or in rocks of free-stone, or quartz, and sometimes in the beds of running waters. When taken out of the earth they are incrusted with an exterior earthy covering, under which is another, consisting of carbonate of lime.

In the Brazils, it is supposed that diamonds might be obtained in greater quantities than at present, if the sufficient working of the diamond mines was not prohibited, in order to prevent that diminution of their commercial value, which a greater abundance of them might occasion.

REMARK...Brazilian diamonds, are in commercial estimation inferior to the oriental ones.

In the rough, diamonds are worth two pounds sterling the carat, or four grains, provided they are without blemish. The expence of cutting and polishing, amounts to about four pounds more. The value however is far above what is now stated when they become considerable in size.

The usual method of calculating the value of diamonds, is by squaring the number of carats, and then multiplying the amount by the price of a single carat: thus supposing one carat to be £2. a diamond of 8 carats is worth £128. being $8 \times 8 \times 2$.

The famous Pigot diamond weighs $188\frac{1}{8}$ grains.

PHYSICAL PROPERTIES OF DIAMOND.

Diamond is always crystallized, but sometimes so imperfectly, that at first sight it might appear amorphous. The figure of the diamond when perfect, is an eight-sided prism. There are also cubical, flat, and round diamonds. It is the oriental diamond which crystallizes into octohedra, and exhibits all the varieties of this primitive figure. The diamond of Brazil crystallizes into dodecahedra.

The texture of the diamond is lamellated, for it may be split or cleft with an instrument of well-tempered steel, by a swift blow in a particular direction. There are however some diamonds which do not appear to be formed of *laminae*, but of twisted and interwoven fibres, like those of knots in wood. These exceed the others greatly in hardness, they cannot be cut or polished, and are therefore called by the lapidaries DIAMONDS OF NATURE.

The diamond is one of the hardest bodies known. It resists the most highly tempered steel file, which circumstance renders it necessary to attack it with diamond powder. It takes an exquisite and lasting polish. It has a great refractive power, and hence its lustre, when cut into the form of a regular solid, is

uncommonly great. The usual colour of diamonds is a light grey, often inclining to yellow, at times lemon colour, violet, or black, seldomer rose-red, and still more rarely green or blue, but more frequently pale brown. The purest diamonds are perfectly transparent. The colourless diamond has a specific gravity which is in proportion to that of water as 3.512 to 1.000, according to Brisson. This varies however considerably. When rubbed it becomes *positively* electric, even before it has been cut by the lapidary.

Diamond is not acted upon by acids, or by any chemical agent, oxigen excepted; and this requires a very great increase of temperature to produce any effect.

The diamond burns by a strong heat, with a sensible flame, like other combustible bodies, attracting oxigen and becoming wholly converted into carbonic acid gas during that process.

It combines with iron by fusion, and converts it like common charcoal, into steel; but diamond requires much more oxigen to burn in than common charcoal does, and even then it consumes but slowly, and ceases to burn the instant its temperature is lowered.

It is considered by modern chemists as PURE CRYSTALLIZED CARBON.

SECT. II.

PROOFS

OF THE

COMBUSTIBILITY OF DIAMOND.

THE combustibility of the diamond is a phenomenon sufficiently interesting to induce us to give an extract of the principal experiments which have served to advance our knowledge upon this subject.

The Emperor Francis I. exposed to a vehement heat, the value of six thousand florins in diamonds and rubies; the diamonds disappeared, but the rubies remained unaltered. These experiments were repeated; and it was ascertained that the diamond lost its polish, scaled off, and was dissipated.

The Grand-duke of Tuscany in 1694 caused experiments to be made by Averoni and Targioni by the mirror of Tschirnhausen, and the diamond disappeared in a few minutes.

These experiments were repeated by the French chemists, Darcet, Cadet, Lavoisier, &c. with equal success. The details of their experiments may be seen in the volumes of the Academy of Sciences, and the Journal de Physique for the year 1772.

Macquer took notice that the diamond dilated, swelled and burnt with a blue flame. Ladriani* mentions an experiment, in which the diamond was fixed to the end of a small iron wire which was heated red hot, and plunged into a vessel filled with oxigen gas. The combustion of the iron communicated itself to the diamond, which burnt in this gas, with a very bright flame.

* Annales de Chem. tom. XI. p. 156.

This experiment however did not succeed with the diamond of Brazil.

Lavoisier and Cadet proved that the combustion of the diamond, in close vessels, like all other combustible bodies, ceased as soon as the oxigen was exhausted, and that it only burnt in proportion to the oxigen presented to it.

De Saussure burnt a diamond by means of the blow-pipe.

But as the sole object of all the former experiments was to ascertain the combustibility of the diamond, no attention was paid to the products it afforded during the process; and it still remained to be determined whether the diamond was a distinct substance or one of the known inflammable bodies. No attempt was made to decide this question, till Lavoisier in 1777 undertook a series of experiments for this purpose. He exposed the diamond to a large lens, and was thus enabled to burn it in a close glass vessel. He observed that the air, in which the diamond had been burnt, became absorbed by water; that it disturbed lime-water, and that the precipitate obtained was soluble in acids with effervescence.

Carbonic acid had therefore been formed. As nothing was present but diamond and oxigen, and as carbonic acid gas consists of charcoal, oxigen, and caloric, the diamond and oxigen must have been converted by caloric into the state of carbonic acid gas; and hence the diamond must have been charcoal.

The diamond is therefore a combustible body, which burns in the same manner in oxigen gas as charcoal does. This strict and accurate consequence is deduced from all the experiments which can be imagined to acquire a perfect demonstration. But that the diamond was *charcoal in its pure and chrystallized state* was left to the determination of modern chemists.

Guyton-Morveau applied the solar heat by means of a great lens, to a diamond placed in a china cup, and surrounded in a proper apparatus, with a confined quantity of oxigen gas.

In one experiment the diamond exhibited, first, a black point at the angle directly struck by the solar rays; after this, it so

became completely black and of a coally appearance; the instant afterwards, brilliant and as it were boiling points were distinctly perceived on the black ground. It now began to diminish in size and in a short time no more than one-fourth was remaining. It was then withdrawn. It was without any marked sharp angles or edges, but still very white, and of a beautiful transparency. The diamond was a second time heated with the solar rays, and in twenty minutes entirely consumed without any residue. During this operation the same phenomena were observed.

A solution of barytes was then introduced over the mercury confining the air in which the diamond had been consumed. It became immediately milky, the volume of the gas diminished, and carbonate of barytes was formed.

In this process a greater quantity of carbonic acid was obtained, than would have been produced, had the diamond been in the same state as common charcoal. For one part of charcoal absorbs during combustion 2.527 of oxigen, and produces 3.575 of carbonic acid; but one part of diamond absorbs somewhat more than four parts of oxigen, and produces five of carbonic acid.

The diamond of which Guyton effected the complete combustion was a native octohedral crystal. It burned in a temperature of about 90 pyrometrical degrees, which in the scale of Wedgwood constitutes a difference of from 183° to 1765°.

We are likewise indebted to Dr. Smithson Tennant for some excellent experiments on the nature of the diamond. His paper of which we shall give an abstract is in the Philosophical Transactions for 1797. Dr. Tennant has taught us a method of effecting the combustion of the diamond in a much easier manner than that stated above. He has proved that by means of nitrate of potash, the combustion may be accomplished in a moderate heat.

The Doctor procured a tube of gold, which having one end closed, served as a retort, to which a glass tube was adapted in order to collect the air produced. To be certain that the gold

vessel was persectly closed, and that it did not contain any thing which could occasion the production of carbonic acid, some nitrate of potash was heated and decomposed in it, and afterwards washed out with water. The solution was examined, but did not exhibit any appearance of carbonic acid.

The diamond was then burnt in this vessel by means of nitrate of potash. When it was thus destroyed, the substance which remained precipitated lime from lime-water, and on the addition of acids, afforded carbonic acid gas and nitrous gas, and therefore consisted of nitrate of potash partly decomposed, and carbonate of potash.

In order to estimate the quantity of carbonic acid which might be obtained from a given quantity of diamonds, two grains and a half of small diamonds were put into the golden tube with a quarter of an ounce of nitrate of potash, the whole was then kept in a strong red heat for about an hour and a half. After the tube had grown cold again, the contents were dissolved in water, consequently the diamonds had been destroyed.

In order to ascertain the quantity of carbonic acid, the contents which had been dissolved, were decomposed by muriate of lime. Hence muriate of potash and carbonate of lime were obtained. This carbonate of lime was separated from the supernatant muriate of potash, and introduced into a glass globe having a tube annexed to it. This globe and tube were then filled with mercury and inverted in a vessel containing the same fluid. The lime by that means was made to occupy the very top of the tube. It now remained to separate the carbonic acid from the lime, it was therefore mixed with muriatic acid; by this means 10.3 ounce measures of carbonic acid gas, or nearly 9.166 grains were separated; but, according to the experiments of Lavoisier, this gas is composed of 72 parts of oxigen and 28 of carbon; 9.166 grains therefore contain 2.56 grains of carbon which is almost the weight of the diamond consumed, and hence it follows, that it was composed of pure carbon, or the pure acidifiable basis of the carbonic acid.

The combustion of the diamond is effected at three different temperatures. At the first and least elevated temperature the diamond assumes a grey and black colour; this is the first degree of oxidation; it is the state of the plumbago and of the antracolite, or incombustible pit-coal.

At the second degree of temperature there is a new, slow and successive combination of oxigen; it then constitutes the habitual state of our charcoal.

Supposing therefore we could operate with sufficient precision to take from the surface of the diamond, the black matter in proportion as it formed, during our experiment for burning it, we should undoubtedly convert the whole diamond into *charcoal.*

At the third degree of combustion the diamond is wholly converted into carbonic acid gas, as we have shewn before.

Guyton has likewise converted soft-iron into cast-steel, by means of the diamond, in the following manner:* A cavity was bored in a block of soft-iron, and a stopper fitted to it of the same metal. Into the cavity was put a diamond, with some filings of the block of iron, to fill the remaining space, after which the stopper was driven in. In this state the whole was put into a crucible and this placed into another. The space between the two crucibles was filled with pure siliceous sand. The external crucible was well closed and luted, and the whole exposed to the strong ignition of a blast-furnace, by which the metal was fused completely; the diamond disappeared and the iron was thus converted into steel.

After all this, it will no doubt be demanded how it happens, that the pure carbon or diamond is so scarce, whilst when combined with oxigen in the state of charcoal it is so abundantly dispersed through nature?

We obtain by our chemical decompositions of bodies charcoal and not diamond. No chemist speaks of our exhaling diamond by respiration, but many of charcoal or at least carbonic acid.

* Annales de Chem. XXXI, p. 328.

To any disbelief of this matter it must be answered, that, iron exists every where under every form except in the state of perfect purity or uninsulated: for the existence of pure native iron is still doubtful. The wonder consists therefore only in the difference between facts and our opinions; it vanishes in proportion as we discover and appropriate the powers of nature to produce the same effects.

The diamond is advantageously used on account of its excessive hardness to engrave on hard stones and glass, or to cut them into convenient pieces. It is also used as an ornament. The extreme hardness, the labour of cutting and polishing it, together with its rarity, render it precious without the assistance of the caprice of fashion.

Before we proceed farther in the description of simple substances, it will be necessary to illustrate the nature and production of *gases*, together with their properties; for the agency of these bodies produces so considerable a number of the phenomena which distinguish some bodies from others, that without a previous acquaintance with them, a great number of the experiments illustrative of the properties of simple substances would be unintelligible.

NATURE

AND

FORMATION OF GASES.

PART XIV.

SECT. I.

NATURE OF GASES.

By the word *gases* we distinguish permanently elastic aeriform fluids, or substances which have the appearance of air, that is to say; they are transparent, elastic, ponderable, invisible,* and not condensible into a liquid or solid state by any degree of cold hitherto known.

Some of the gases exist in nature, without the aid of art, and may therefore be collected; others on the contrary, are only producible by artificial means.

All gases are combinations of certain substances, reduced to the gazeous form by the addition of caloric and light. It is therefore necessary to distinguish in every gas, the matter of heat which acted the part of a solvent, and the substance which forms the basis of the gas. Gases are not contained in those

* Oxigenated muriatic acid gas, and nitrous acid gas, are the only exceptions to this rule.

substances from which we obtain them in the state of gas, but owe their formation to the expansive property of caloric.

The bases of some gases are known to us and may be exhibited in an uncombined state; others again are not producible by art.

FORMATION OF GASES.

It has been mentioned before (p. 84.) that the different forms under which bodies appear depend upon a certain quantity of caloric, chemically combined with them. The very formation of gases corroborates this truth. Their production totally depends upon the combination of the particular substances with caloric; and those we call permanently elastic, are only so, because we cannot so far reduce their temperature, as to dispose them to part with it; otherwise they would undoubtedly become fluid or solid.

Water, for instance, is a solid substance in all degrees below 32° of Fahrenheit's scale; above this temperature it combines with caloric and becomes a fluid. It retains its fluidity under the ordinary pressure of the atmosphere, till its temperature is augmented to 212°. It then combines with a larger portion of caloric, and is converted, *apparently*, into gas, or at least into elastic vapour; in which state it would continue if the temperature of our atmosphere was above 212°. Gases are therefore solid substances between the particles of which a repulsion is established by the quantity of caloric.

But as in the gazeous water or steam, the caloric is retained with but little force, on account of its quitting the water when the vapour is merely exposed to a lower temperature, we do not admit steam amongst the class of gases, or permanent aeriform elastic fluids. In gases caloric is united by a very forcible affinity, and no diminution of temperature, or pressure that has ever yet been effected, can separate it from them. Thus the air of our atmosphere in the most intense cold, still remains in the

aeriform state; and hence is derived the essential characters of gases, namely; *that they shall remain aeriform, under all variations of pressure and temperatures.*

In the modern nomenclature, the name of every substance existing in the aeriform state is derived from its solid base; and the term gas is used to denote its existence in this state.

In order to illustrate the formation of gases, or to show in what manner caloric is combined with them, the following experiment may serve.

Experiment I.

Put into a retort capable of holding half a pint of water, two ounces of muriate of soda, (common salt), pour on it half its weight of sulphuric acid and apply the heat of a lamp, a great quantity of gas is produced which might be collected and retained over mercury. But to serve the purpose of this experiment let it pass through a glass receiver having two openings, into one of which the neck of the retort passes, whilst from the other a bent tube proceeds which ends in a vessel of water.... Before closing the apparatus, let a thermometer be included in the receiver to show the temperature of the gas. It will be found that the mercury in the thermometer will rise only a few degrees, whereas the water in the vessel which receives the bent tube, will soon become boiling hot.

Rationale....Common salt consists of muriatic acid united to soda, on presenting sulphuric acid to this union, a decomposition takes place. The sulphuric acid unites by virtue of its greater affinity to the soda and forms sulphate of soda, or Glauber's salt; the muriatic acid becomes therefore disengaged, and takes the gazeous form in which it is capable of existing in our temperature. To trace the caloric during this experiment as was our object, we must remark that it first flows from the lamp to the disengaged muriatic acid, and converts it into gas;

but the heat thus expended is chemically united, and therefore not appreciable by the thermometer. The caloric however is again evolved, when the muriatic acid gas is condensed by the water with which it forms liquid muriatic acid.

In this experiment we therefore trace caloric in a chemical combination producing gas, and from this union we again trace it in fire or sensible heat.

Such in general is the cause of the formation and fixation of gases. It may be further observed that each of these fluids, loses or suffers the disengagement of different quantities of heat, as it becomes more or less solid in its new combination, or as that combination is capable of retaining more or less specific heat.

PNEUMATIC APPARATUS.

The discovery of aeriform or gazeous fluids has occasioned the necessity of some peculiar instruments, by means of which those substances may be conveniently collected and submitted to examination. The principal ones for that purpose are styled the *pneumatic apparatus*.

THE PNEUMATIC RESERVOIR OR CISTERN

Is made either of wood or strong sheet-iron tinned, japanned or painted. A trough of about two feet long, sixteen inches wide, and fifteen high, has been found to be sufficient for most experiments. Two or three inches below its brim, a horizontal shelf is fastened, in dimension about half or one-third part of the width of the trough. In this shelf are several holes: these holes must be made in the centre of a small excavation, shaped like a funnel, which is formed in the lower part of the shelf.

This trough is filled with water sufficient to cover the shelf to the height of an inch.

The use of this shelf is to support receivers, jars, or bell-glasses, which being previously filled with water are placed invertedly, their open end turned down upon the above-mentioned holes, through which the gases, conveyed there and directed by means of the funnel-shaped excavations rise in the form of air-bubbles, into the receiver.

When the gazeous fluids are capable of being absorbed by water, as is the case with some of them, the trough must be filled with mercury. The price and gravity of this fluid make it an object of convenience and economy, that the trough should be smaller than when water is used.

A mercurial trough is best cut in marble, free-stone, or a solid block of wood. A trough about 12 inches long, 3 inches wide, and 4 deep is sufficient for all private experiments.

SECT. II.

METHOD OF COLLECTING GASES AND TRANSFERRING THEM FROM ONE VESSEL TO ANOTHER.

PREVIOUS to undertaking experiments on gases, it may be well for the unexperienced operator to accustom himself to the dexterous management of collecting and transferring common air.

If we are desirous of transmitting air from one vessel to another, it is necessary that the vessel destined to receive it, be full of water or some fluid heavier than air. For that purpose take a wide mouthed bell-glass or receiver, plunge it under the water in the trough in order to fill it, then raise it with the mouth downwards and place it on the shelf of the trough, so as to cover one or more of the holes in it.

It will now be full of water and continue so as long as the mouth remains below the surface of the fluid in the cistern, for in this case the water is sustained in the vessel by the pressure of the atmosphere, in the same manner as the mercury is sustained in the barometer. It may without difficulty be imagined, that if common air (or any other fluid resembling common air in lightness and elasticity) be suffered to enter the inverted vessel filled with water, it will rise to the upper part on account of its levity, and the surface of the water will subside. To exemplify this, take a glass or any other vessel in that state which is usually called *empty*, and plunge it into the water with its mouth

downwards, scarce any of it will enter the glass, because its entrance is opposed by the elasticity of the included air; but if the vessel be turned with its mouth upwards it immediately fills and the air rises in bubbles to the surface. Suppose this operation to be performed under one of the jars or receivers which are filled with water and placed upon the perforated shelf, the air will ascend in bubbles as before, but instead of escaping, it will be caught in the upper part of the jar and expel part of the water it contains.

In this manner we see that air may be emptied out of one vessel into another by a kind of inverted pouring, by which means it is made to ascend from the lower to the upper vessel. When the receiving vessel has a narrow neck the air may be poured in a similar manner through an inverted funnel inserted in its mouth.

If the air is to be transferred from a vessel that is stopped like a bottle, the bottle must be unstopped with its orifice downwards in the water; and then inclined in such a manner that its neck may come under the perforated excavation of the shelf. The gas will escape from the bottle and passing into the vessel destined to receive it, will ascend in it, in the form of bubbles.

In whatever manner this operation is performed, the necessity of the excavation in the lower part of the shelf may be readily conceived. It is as mentioned before destined to collect the gas which escapes from the vessel, and direct it in its passage towards the vessel adapted to receive it. Without this excavation the gas, instead of proceeding to the place of its destination, would be dispersed and lost.

The vessels or receivers for collecting the disengaged gases should be glass cylinders, jars, or bell-glasses of various sizes; some of them should be open at both ends, others should be fitted with necks at the top, ground perfectly level, in order that they may be stopped by ground flat pieces of metal, glass, slate,

&c. others should be furnished with ground stoppers. Some should be graduated into cubic inches, and sub-divided into decimal or other equi-distant parts. Besides these, common glass bottles, tumblers, &c. may be used.

CLASSIFICATION OF GASES.

All the elastic aeriform fluids with which we are hitherto acquainted are generally divided by systematic writers into two classes; namely, those that are *respirable* and *capable of maintaining combustion*, and those that are *not respirable* and *incapable of maintaining combustion*. This division indeed has its advantage; but the term respirable in its physico-logical application has been very differently employed by different writers. Sometimes by the respirability of a gas has been meant its power of supporting life, when repeatedly applied to the blood in the lungs. At other times all gases have been considered respirable which were capable of introduction into the lungs by voluntary efforts, without any relation to their vitality. In the last case, the word respirable seems to us most properly employed, and in this sense it will be used hereafter.

Non-respirable gases are those, which when applied to the external organs of respiration, stimulate the muscles of the epiglottis, in such a manner as to keep it perfectly close on the glottis; thus preventing the smallest particle of gas from entering into the bronchia, in spite of voluntary exertions.

Of respirable gases, or those which are capable of being taken into the lungs by voluntary efforts, according to their conditions, only one has the power of uniformly supporting life, namely, atmospheric air; other gases when respired, sooner or later impair the health of the human constitution, or perhaps occasion death; but in different modes.

Some gases effect *no positive* change in the blood; animals immersed in it, die of a disease produced by the privation of

atmospheric air, analogous to that occasioned by their submersion in water.

Others again produce *some positive* change in the blood, as appears from the experiments of Dr. Beddoes and Professor Davy. They seem to render it incapable of supplying the nervous and muscular fibres with principles essential to sensibility and irritability. These gases therefore destroy animal life on a different principle.

It is obvious therefore that the above classification does not hold good in all respects, but is capable of misleading the student. We shall not divide the gases we are going to treat of into different classes; for we do not see the advantage which can arise from any division: we shall therefore examine first those which are simple, the bases of which cannot be exhibited in an insulated state, namely, oxigen, nitrogen, and hidrogen gas. We shall then consider the combination of these gases with each other, in order to understand some of the most important phenomena in which they are concerned, together with the rest of of those gases, of which the bases may be exhibited experimentally.

OXIGEN GAS.

PART XV.

SECT. I.

PROPERTIES OF OXIGEN GAS.

OXIGEN Gas is an elastic invisible fluid like common air, capable of indefinite expansion and compression. It has neither taste or odour, nor does it show any traces of an acid. Its specific gravity, as determined by Kirwan, is 0.00135, that of water being 1.0000; it is therefore 740 times lighter than the same bulk of water. Its weight is to atmospheric air as 1103 to 1000. 116 cubic inches of oxigen gas weigh 39.38 grains. It is not absorbed by water, but entirely absorbable by combustible bodies, which at the same time disengage its caloric and light, producing in consequence a strong heat and flame. It rekindles almost extinct combustible bodies. It is indispensible to respiration; and is the cause of animal heat. It hastens germination. It combines with every combustible body, with all the metals, and with the greater number of vegetable and animal substances. It is considered as the cause of acidity; and from this last property is derived the name *oxigen*, a word denoting the origin of acidity.

The act of its combining with bodies is called *oxidation*, or *oxigenation*; and the bodies with which it is combined are called *oxids*.

Oxigen gas is the chief basis of the pneumatic doctrine of chemistry.

METHODS OF OBTAINING OXIGEN GAS.

We are at present acquainted with a great number of bodies from which we may, by art, produce oxigen gas. It is most amply obtained from the oxids of manganese, or mercury; from nitrate of potash; from the green leaves of vegetables, and from oxigenated muriate of potash, or soda. Besides these, there are a great many other substances from which oxigen gas may be procured.

1. In order to procure oxigen gas in a state of great purity, pure oxigenated muriate of potash or soda, must be made use of. With this view put some of the salt into a small earthen or glass retort, the neck of which is placed under the shelf of the pneumatic trough filled with water; and heat the retort by means of a lamp. The salt will begin to melt, and oxigen gas will be obtained in abundance and of great purity, which may be collected and preserved over water.

RATIONALE...Oxigenated muriate of potash consists of oxigenated muriatic acid and potash; at an elevated temperature a decomposition of the oxigenated muriatic acid takes place; its oxigen unites to the caloric and forms oxigen gas. The oxigenated acid becomes therefore converted into simple muriatic acid, which remains in the retort united to the potash, in the form of muriate of potash.

2. Oxigen gas may likewise be obtained from the green leaves of vegetables.

For this purpose fill a bell-glass with water, introduce fresh gathered green leaves under it, and place the bell or receiver inverted in a vessel containing the same fluid; expose the

apparatus to the rays of the sun, and very pure oxigen gas will be liberated.

The emission of oxigen gas is proportioned to the vigour of the plant and the vivacity of the light; the quantity differs in different plants and under different conditions. (See page 120.)

Rationale...It is an established fact, that plants decompose water and probably carbonic acid, which serve for their nourishment; they absorb the hidrogen and carbon of these fluids, disengaging part of the oxigen in a state of purity. Light however favours this decomposition greatly, it seems to serve for melting the oxigen and thus forms it into oxigen gas; in proportion as it becomes disengaged, the hidrogen becomes fixed in the vegetable and combines partly with the carbon, and partly with the oxigen, to form the oil, &c. of the vegetable.

3. Nitrate of potash is another substance frequently made use of for obtaining oxigen gas, in the following manner:

Take any quantity of this salt, introduce it into a coated earthen or glass retort, and fit to it a tube, which must be plunged into the pneumatic trough, under the receiver filled with water. When the apparatus has been properly adjusted, heat the retort gradually till it becomes red-hot; the oxigen gas will then be disengaged rapidly.

The gas obtained in this way is also very pure, especially if the last portion be kept separate.

Rationale...Nitrate of potash consists of nitric acid and potash. Nitric acid consists again of oxigen and nitrogen. On exposing the salt to ignition, a partial decomposition of the acid takes place; the greatest part of the oxigen of the nitric acid unites to caloric, and appears under the form of oxigen gas. The other part remains attached to the potash in the state of nitrous acid. The residue in the retort is therefore nitrite of potash, if the process has been carefully conducted.

Remark...If too much heat be applied, particularly towards the end of the process, a total decomposition of the nitric acid takes place, the oxigen gas in that case will therefore be mingled

with nitrogen gas. The weight of the two gases when collected will be found to correspond very exactly with the weight of the acid which had been decomposed. The residue then left in the retort is potash.

4. Black oxid of manganese however is generally made use of for obtaining oxigen gas, on account of its cheapness. This native oxid is reduced to a coarse powder; a stone or rather an iron retort is then charged with it and heated. As soon as the retort becomes ignited, oxigen gas is obtained plentifully.

RATIONALE...Black oxid of manganese is the metal called manganese fully saturated with oxigen, together with many earthy impurities; on applying heat, part of the solid oxigen quits the metal and unites to caloric in order to form oxigen gas, the remainder of the oxigen remains united to the metal with a forcible affinity; the metal therefore re-approaches to the metallic state or is found in the state of a grey oxid of manganese.

One pound of the best manganese yields upwards of 1400 cubic inches of oxigen gas, nearly pure. If sulphuric acid be previously added to the manganese, the gas is produced by a less heat and in a larger quantity; a glass retort may then be used, and the heat of a lamp is sufficient.

5. Red oxid of mercury yields oxigen gas in a manner similar to that of manganese.

RATIONALE...This oxid consists likewise of solid oxigen and mercury, the combination of which takes place on exposing mercury to a heat of about 610° Fahr. At this degree it attracts oxigen and becomes converted into an oxid; but if the temperature be increased to about 1000° the attraction of oxigen is changed. The oxigen then attracts caloric stronger than it did the mercury, it therefore abandons it, and forms oxigen gas. The mercury then re-appears in its metallic state. (See p. 50.)

6. Red oxid of lead yields oxigen gas on the same principle.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF OXIGEN GAS.

DECOMPOSITION OF OXIGEN GAS, BY BODIES DESTITUTE OF METALLIC PROPERTIES.

Experiment I.

Combustion of phosphorus in oxigen gas.

FILL a bell-glass or receiver with oxigen gas, confine it by mercury, and introduce a piece of phosphorus through the quicksilver which immediately will rise to the surface of it; then set fire to the phosphorus by means of a crooked heated iron wire, introduced so as to touch it without disturbing the vessel. It will burn with a very brilliant flame. A considerable quantity of caloric and light will be liberated, and the whole inside of the glass will be covered with a white flaky crust, which will be found to be phosphoric acid; and the mercury will have ascended considerably.

Rationale...This experiment proves that a decomposition of the oxigen gas has taken place. The phosphorus at a certain degree of heat is capable of decomposing this gas; it attracts its ponderable basis the oxigen, and becomes converted into phosphoric acid; the light and heat which kept the oxigen in a gazeous state, together with those of the phosphorus, are then disengaged in the form of fire.

If the phosphorus is weighed before the experiment, and the quantity of oxigen gas has been also ascertained, the weight of the produced acid will be found equal to the sum of the weights of the phosphorus consumed and oxigen absorbed, if the experiment has been conducted carefully. Forty grains of phosphorus absorb generally sixty-five of oxigen.

If the oxigen gas be pure, the residuum after combustion is as pure as the gas employed; this proves that nothing could escape from the phosphorus capable of altering the purity of the oxigen gas, and that the only action of the phosphorus is to separate the oxigen from the caloric with which it was before united.

This property of being convertible into an acid belongs to all combustible bodies; hence the combination of oxigen with such a body is called *oxigenation*.

Experiment II.

Combustion of sulphur in oxigen gas.

This experiment is best performed by filling a large receiver with oxigen gas, in the water-apparatus, and removing it by means of a flat dish into the mercurial trough, taking care to leave a little water over the mercury. When this is done put a small piece of sulphur into a copper ladle, set fire to it by means of a candle and blow-pipe, and introduce it into the gas. The sulphur will burn with a beautiful blue flame, when the fumes have disappeared, the water over the mercury will be found to have an acid taste, it will turn blue vegetable colours red, and effervesce with carbonated alcalies. It is therefore an acid, and as it is composed of sulphur and oxigen it is called sulphuric acid. If the respective quantities of gas, sulphur, and water, have been previously ascertained, the water will be found to have increased in weight, as much as the sum of the weights of the sulphur and oxigen consumed.

RATIONALE...Sulphur is a simple combustible body, which possesses the property of decomposing oxigen gas at a high temperature, by attracting the oxigen from the caloric with which it was combined, in order to be converted into sulphuric acid.

EXPERIMENT III.

Combustion of charcoal in oxigen gas.

The oxigenation of charcoal may be effected like that of phosphorus in the receiver placed over mercury. But as the heat of the red-hot iron is not sufficient to ignite the charcoal, a small piece of tinder with a minute particle of phosphorus are brought in contact with it; these being set on fire will kindle the charcoal, which then will burn and throw out scintillating sparks in all directions.

After the combustion ceases, it will be found that the elastic fluid under the receiver has not disappeared, as was the case in the former experiments; but that a new peculiar kind of gas is formed. This air is unfit for respiration and incapable of maintaining combustion. It is greatly absorbed by cold water, and vanishes by lime-water, barytic-water, or by other alcalies, which first are rendered turbid, and prove it to be an acid, consisting of charcoal and oxigen; hence it is called carbonic acid gas. Whatever quantity of gas remains after the absorption by alcalies, is that portion of oxigen gas, which has escaped the action of the charcoal during the combustion.

RATIONALE...The charcoal in this case likewise effects a decomposition of the oxigen gas. When charcoal is ignited, its affinity for oxigen is stronger than that of caloric, it therefore unites to it and forms carbonic acid which assumes the gazeous state at the temperature of our atmosphere. The light and heat become liberated and appear under the form of fire.

DECOMPOSITION OF OXIGEN GAS BY METALLIC SUBSTANCES.

Oxigen has likewise a great affinity for another kind of combustible bodies, we mean those called metals; particularly when heated to a certain degree. All metallic bodies, except gold, silver, and platina, have the property of decomposing oxigen gas, by attracting its ponderable basis (the solid oxigen) from the caloric and light, which kept it in its gazeous state. They then lose their qualities and approach to the acid state.

Experiment I.

Combustion of iron in oxigen gas.

This experiment may be exhibited in the most convenient manner as follows: a glass receiver, with a narrow open neck, must be provided. It may be closed at the top with a cork, or a rough-ground flat piece of glass or metal. It is to be filled with water and put upon the shelf of the pneumatic trough. Oxigen gas is then conveyed into it in the usual manner. When the receiver is filled with gas, a shallow bason or dish with water must be brought near it, so that the receiver may be removed with the gas, and easily slid into the bason. The gas is thus confined by the water and the receiver may be removed to any convenient place. Iron wire of about $\frac{1}{30}$ of an inch in diameter must be coiled tightly round a stick of wood or glass of about half an inch in diameter; the stick is then withdrawn and the wire will form a length of spiral rings. This wire, extended to about the inside length of the receiver, must be fixed in a cork so that it may hang vertically, and may be readily introduced at the top of the receiver and kept by means of the cork, firm therein; at the other extremity of the wire a little thread dipped in sulphur, or a piece of wood is to be

fixed. The thread or wood is then lighted and the wire quickly introduced into the receiver; an intense deflagration of the wire immediately takes place, throwing out a number of brilliant sparks, ascending in a spiral direction with a beautiful sun-like body, giving in a darkened room a luminous appearance inconceivably striking.

If we examine the weight of the iron after combustion we find it augmented in proportion to the quantity of oxigen it has absorbed. It has at the same time lost its metallic splendor, and obtained properties different from those it possessed before.

The use of the heat employed for the first ignition is to separate the particles of the metal from each other, and to diminish the attraction of cohesion or aggregation.

RATIONALE...The iron when heated to a certain degree decomposes the oxigen gas; the equilibrium of the attraction subsisting between the caloric and solid oxigen being interrupted, it is acted upon by two separate and opposite forces, that of the attraction for caloric to remain in the gazeous state, and that exerted by the metal; the latter power being greater, it unites with it and gives out at the same time its caloric and light. The new substance produced, consisting of oxigen and iron, is called *oxid of iron*. It is not an acid, but it is changed to an intermediate substance, approaching to the acid state, though not possessing all the requisite properties.

EXPERIMENT II.

Combustion of zinc in oxigen gas.

Take some turnings of zinc, form a ball of them, and affix it to a copper wire; insert a small bit of phosphorus into the ball, set fire to it, and introduce it quickly into a bottle filled with oxigen gas; the zinc will thus take fire, and burn with a beautiful green flame surrounded by a white one.

RATIONALE...This experiment is analogous to the former; the zinc unites to the oxigen of the gas, at an elevated temperature, and the result is an oxid of zinc.

EXPERIMENT III.

Combustion of arsenic in oxigen gas.

Take a piece of metallic arsenic, dip it into oil of turpentine, and place it in a copper ladle, then set fire to the oil which adheres to it by means of a candle, and introduce the ladle into a receiver filled with oxigen gas; the metal will take fire and burn with a thick flame, and the whole receiver will be filled with white vapours.

RATIONALE...In this experiment arsenic acid is formed by the oxigen combining with the metal.

EXPERIMENT IV.

If a current of oxigen gas be conveyed to filings of metals, they will burn with great rapidity.

For this purpose fill a large bladder with oxigen gas, and adapt to it a tube; by pressing the bladder and ejecting the gas on a piece of excavated ignited charcoal, into which filings of metal have been put, the metal will burn rapidly.

The filings of metals which exhibit the most brilliant appearance are those of zinc, copper, antimony, iron, and steel.

DECOMPOSITION OF OXIGEN GAS BY VARIOUS OTHER SUBSTANCES.

EXPERIMENT I.

If a lighted wax taper fixed to an iron wire be let down into a vessel filled with oxigen gas, it will burn with great splendor.

If the taper be blown out and let down into the vessel of gas while the snuff remains red-hot, it instantly rekindles with a slight explosion, and burns vividly.

Experiment II.

A piece of the bark of charcoal fastened to a copper wire ignited, and then immersed in the gas, throws out brilliant sparks.

Experiment III.

A mixture of nitrate of strontia and charcoal powder, previously ignited, burns with a *rose-coloured flame*.

Experiment IV.

A mixture of one part of boracic acid, and three of charcoal, burns *green*.

Experiment V.

One part of nitrate of barytes and four of charcoal powder burn with a *yellow flame*.

Experiment VI.

Equal parts of nitrate of lime and charcoal powder burn *orange-red*.

Those who are desirous of multiplying experiments of this kind, may present to oxigen gas under similar conditions, a variety of other combustible substances. The phenomena attending the combustion of many of them are extremely vivid and beautiful; for instance, cotton dipt in oil of turpentine, or ardent spirit, resin, camphor, elastic-gum, &c.

HIDROGEN GAS.

PART XVI.

SECT. I.

PROPERTIES OF HIDROGEN GAS.

THIS gas, which was formerly called inflammable air, was discovered by Mr. Cavendish, in the year 1768, though it had been noticed long before by the ancients. The famous philosophical candle attests the antiquity of this discovery.

Hidrogen gas, like oxigen gas, is a triple compound, consisting of the ponderable base of hidrogen, (page 138) caloric, and light. It possesses all the mechanical properties of atmospheric air. It is the lightest substance whose weight we are able to estimate: when in its purest state, and free from moisture, it is about thirteen times lighter than atmospheric air. It is not fitted for respiration; animals, when obliged to breathe in it, die almost instantaneously. It is decomposed by living vegetables, and its basis becomes one of the constituents of oil, resin, &c. It is inflammable, and burns rapidly when kindled, *in contact with atmospheric air or oxigen gas,* by means of the electric spark, or by an inflamed body; and burns when pure with a blue lambent flame; but all burning substances are immediately

extinguished when immersed in it. It is therefore incapable of supporting combustion. It is not injurious to growing vegetables. It is unabsorbable by most substances; but water absorbs about $\frac{1}{13}$ of its bulk. It is capable of dissolving carbon, sulphur, phosphorus, arsenic, and many other bodies. When its basis combines with that of oxigen gas, water is formed;* with nitrogen it forms ammonia. It does not act on earthy substances. It is decomposible by a great variety of bodies.

METHODS OF OBTAINING HIDROGEN GAS.

A ready method of obtaining hidrogen gas consists in subjecting water to the action of a substance which is capable of decomposing this fluid.

1. For this purpose let sulphuric acid, previously diluted with four or five times its weight of water, be poured on iron filings or bits of zinc, in a small retort or gas-bottle, called a pneumatic flask or proof; as soon as the diluted acid comes in contact with the metal a violent effervescence takes place, and hidrogen gas escapes without external heat being applied. It may be collected in the usual manner over water, taking care to let a certain portion escape, on account of the atmospheric air contained in the disengaging vessel.

RATIONALE...The production of hidrogen gas is owing to the decomposition of water. The iron or zinc, when in contact with this fluid, in conjunction with sulphuric acid, has a greater affinity to oxigen than the hidrogen has; the oxigen therefore unites to it and forms an oxid of that metal which is instantly attacked and dissolved by the acid; the other constituent part of the water the hidrogen is set free, which by uniting with caloric

* Hence its name *Hidrogen* which is derived from ὑδωρ *water*, and γινομαι *I am born*.

assumes the form of hidrogen gas. The oxigen is therefore the bond of union between the metal and the acid.

The hissing noise or effervescence observable during the process is owing to the rapid motion excited in the mixture by means of the great number of air-bubbles quickly disengaged and breaking at the surface of the fluid.

REMARK...We see in this case that *two* substances exert an attraction, and are even capable of decomposing jointly a *third*, which neither of them is able to do singly, *viz.* if we present sulphuric acid alone, or iron or zinc alone to water, they cannot detach the oxigen from the hidrogen of that fluid; but if both are applied, a decomposition is instantly effected. This experiment therefore proves that the agency of chemical affinity between two or more bodies may lie dormant, until it is called into action by the interposition of another body, which frequently exerts no energy upon any of them in a separate state. *(See Chemical Affinity, law* V. *p.* 43 *and* 52, *line* 22...28.) Instances of this kind were formerly called *predisposing affinities.*

2. Iron in a red heat has also the property of decomposing water, by dislodging the oxigen from its combination with hidrogen in the following manner.

Let a gun-barrel having its touch-hole screwed up pass through a furnace or large crucible perforated for that purpose, taking care to incline the barrel at the narrowest part; adjust to its upper extremity a retort charged with water, and let the other extremity terminate in a tube introduced under a receiver in the pneumatic trough. When the apparatus is thus disposed, and well luted, bring the gun-barrel to a red heat, and when thoroughly red-hot, make the water in the retort boil; the vapour when passing through the red-hot tube will yield hidrogen gas abundantly.

RATIONALE...In this experiment the oxigen of the water combines with the iron at a red heat, so as to convert it into an oxid, and the caloric applied combines with the hidrogen of the water, and forms hidrogen gas. It is therefore the result of a double

affinity, that of the oxigen of the water with the metal, and that of its hidrogen with caloric.

The more caloric is employed in the experiment of decomposing water by means of iron, &c. the sooner is the water decomposed.

Hidrogen gas is frequently found in great abundance in mines and coal-pits, where it is sometimes generated suddenly and becomes mixed with the atmospheric air of these subterraneous cavities. If a lighted candle be brought in, this mixture often explodes and produces the most dreadful effects. It is called by miners *fire-damp*. It generally forms a cloud in the upper part of the mine on account of its levity, but does not mix there with atmospheric air unless some agitation takes place. The miners frequently set fire to it with a candle, laying at the same time flat on their faces to escape the violence of the shock. An easier and more safe method of clearing the mine is by leading a long tube through the shaft of it, to the ash-pit of a furnace; by this means the gas will be conducted to feed the fire.

Hidrogen gas in whatever manner produced, *always* originates from water, either in consequence of a preceding decomposition, in which it had been combined in the state of solid or fixed hidrogen, with one of the substances employed, or from a decomposition of water actually taking place during the experiment.

Remarks...There are instances recorded of a vapour issuing from the stomach of dead persons, which took fire on the approach of a candle. We even find accounts in several works of the combustion of living human beings, which appears to be spontaneous. Dr. Swediaur related some instances of porters at Warsaw, who having drank abundantly of spirit, fell down in the street with the smoke issuing out of their mouths; and people came to their assistance, saying they would take fire; to prevent which they made them drink a great quantity of milk, or used a more singular expedient by causing them to swallow the urine of the bystanders, immediately on its evacuation.

However difficult it may be to give credit to such narratives, it is equally difficult to reject them entirely, without refusing to admit the numerous testimonies of men, who were for the most part worthy of credit. *Citizen Lair* has collected all the circumstances of this nature which he found dispersed in different books and has rejected those which did not appear to be supported by respectable testimony, to which he has added some others related by persons still living. These narratives are nine in number, they were communicated to the philomatic society at Paris, and inserted in the bulletin, Thermidor, An. 5, No. 29.

The cause of this singular phenomenon has been attributed to a developement of hidrogen gas taking place in the stomachs of these individuals.

Citizen Lair believes that the bodies of these people were not burned perfectly spontaneously, but it appeared to be owing to some very slight external cause, such as the fire of a candle, taper, or pipe.

SECT. II.

EXPERIMENTAL PROOFS

OF

THE PROPERTIES OF HIDROGEN GAS.

Experiment I.

Hidrogen gas is considerably lighter than atmospheric air.

FILL a receiver or wide-mouthed bottle with hidrogen gas, and let it stand for a few minutes with its open mouth upwards exposed to the air. On letting down a lighted candle into the bottle the gas will be found to have escaped, for the candle will burn with its usual splendor.

If another jar filled with the gas be placed with its mouth downwards the air will be prevented from ascending by the bottom and sides of the vessel, as may be proved by inserting a lighted candle, which will be instantly extinguished.

Experiment II.

Soap bubbles filled with hidrogen gas ascend rapidly.

Fill with hidrogen gas, a bladder, and adapt to it a common tobacco pipe; dip the bowl of the pipe into a lather of soap, squeeze it gently in order to form a bubble, and detach it in the usual manner. These bubbles will rise rapidly into the air; if

a lighted taper be presented to them, they catch fire and burn without noise.

If into a bason of soap-suds a mixture of hidrogen gas and atmospheric air be blown, by means of a bladder and pipe, so as to form bubbles over a considerable part of the surface of the suds, and a lighted match be then presented to it, the whole will explode with a loud report.

The theory of balloons or aerostatic machines is founded on the levity of hidrogen gas. It is sufficient that the weight of the balloon itself and of the inclosed gas should be lighter than an equal bulk of common air, and it must rise till its weight is in an equilibrium with an equal volume of the surrounding medium. The theory of the *Mongolfiers* is very different from this.

Experiment III.

Hidrogen gas extinguishes burning bodies.

Bring an inverted jar filled with hidrogen gas, over the flame of a candle and depress the jar at once, so that the lighted wick may be wholly surrounded by the gas. The candle will immediately be extinguished.

Experiment IV.

Hidrogen gas is unfit for combustion.

Introduce hidrogen gas into a jar filled with mercury; when the mercury is displaced pass up into the gas a piece of tinder to which is affixed a little phosphorus, and apply to the latter a heated wire. As soon as the phosphorus is touched with the hot wire it will melt but will not burn; the gas is therefore unfit for combustion.

Experiment V.

Hidrogen gas is unfit for respiration.

Take a bell-glass ground at the top; having filled it with hidrogen gas put a bird or any other animal into it, and cover it with a ground-flat piece of glass to prevent the fluid from escaping. The animal confined in the gas will be thrown into violent convulsions and soon expire, but merely on account of atmospheric air being excluded, for the hidrogen gas has suffered no alteration.

Experiment VI.

Hidrogen gas is only inflammable in contact with atmospheric air, or oxigen gas.

Fill a narrow-mouthed phial with hidrogen gas, and take it from the pneumatic trough by placing the thumb on the mouth thereof to prevent the gas from escaping. If a lighted taper be applied to the mouth of the bottle the gas will take fire and burn with a lambent flame. The gas will only burn in contact with the atmospheric air; the flame will descend gradually till all the gas is consumed; but if the taper be immersed in it, it becomes extinguished as we have seen before, experiment III.

If the hidrogen gas be pure the flame is of a blue colour; but if the gas holds any substance in solution, which is generally the case, the flame is tinged of different colours according to the substance. It is most usually reddish because the gas holds in solution a little charcoal.

Experiment VII.

The philosophical candle which cannot be easily blown out.

Fill with hidrogen gas a bell-glass furnished with a capillary tube; compress the gas by making the bell descend below the

level of the water in the pneumatic trough, then apply a lighted taper to the upper extremity of the tube, the gas will take fire and exhibit a candle, which will burn till all the gas is exhausted.

Artificial fire-works may be constructed by filling bladders with hidrogen gas, and connecting them with revolving jets, tubes, &c. bent in different directions and formed into various figures, which are pierced with holes of different sizes. The air being forced through these holes by pressing the bladders, will, when inflamed, exhibit a curious fire-work without noise or smoke.

It is on similar principles that Mr. Cartwright's fire-works were formed.

By the combination of the inflammable property of hidrogen gas and the effects of electricity, a curious philosophical lamp has been invented by *Volta*, which by the turning of a stop-cock only, may instantly be lighted many hundred times: for a particular description of which we refer our readers to Adams's Lectures on Natural Philosophy, vol. II. p. 98.

All these experiments show that hidrogen gas, which is not inflammable when alone, possesses that property when in contact with atmospheric air.

Hidrogen gas burns in proportion as it is environed with a larger quantity of atmospheric air, or oxigen gas. As hidrogen gas, and oxigen, or atmospheric air have a like aggregation, it is possible to mix them in such a manner, as that every particle of each gas shall be contiguous to a particle of the other, in which case they will burn with great rapidity.

Experiment VIII.

Fill a strong bottle capable of holding about four ounces of water in such a manner that there may be one part of hidrogen gas and two of atmospheric air. On applying a lighted taper the mixture will not burn silently, but the whole will ex-

plode with a loud report, and the inside of the bottle will become moist.

Remark...It is prudent to wrap a handkerchief round the bottle, to prevent it from doing any injury if it should burst. The safest way of making this experiment is with a bottle of elastic gum.

The same experiment may be repeated with oxigen gas instead of atmospheric air, changing the proportions and mixing only one part of oxigen gas with two of hidrogen. The explosion will then be much louder than in the foregoing experiment.

Experiment IX.

To charge and fire a cannon or pistol, by means of hidrogen gas.

This experiment may be made advantageously by means of an apparatus, sold under the name of the inflammable air pistol or cannon.

To charge this pistol nothing more is necessary, but to introduce its open end into a wide-mouthed bottle, filled with a mixture of oxigen and hidrogen gas; leaving it in for a few seconds, it is then to be stopped with a cork, and may be fired by the electric spark, taken either from the prime conductor of the machine or a charged Leyden vial.

Experiment X.

The production of water by detonating hidrogen and oxigen gases

Is founded on the same principle. Take a strong glass tube about half an inch in diameter and twelve inches long, closed at one end and graduated into cubic inches or any other equi-distant parts. About half an inch from the closed end or top, two small holes are drilled opposite to each other, and into each of these a wire or conductor is to be cemented, so that the two

points may be distant from each other, within the tube, about one-eighth of an inch or less. Into this tube standing in water, two parts in bulk of hidrogen gas, and five parts of atmospheric air, is transferred. The tube is then to be firmly held, and an electric spark is passed, by means of the conductors, through the mixture of the gases; an immediate explosion takes place, the volume of the gases will be diminished, and the water will ascend in the tube; for the whole of the hidrogen gas is consumed, and likewise all that part of the common air which consisted of oxigen gas, and there is formed a quantity of water equal in weight to these two bodies.

RATIONALE...The hidrogen gas robs the atmospheric air of the whole portion of oxigen gas it contained, this mixture being fired by the electric spark disappears and forms water. The residue therefore indicates the quantity of nitrogen gas which was contained in the given bulk of atmospheric air with considerable accuracy.

REMARK...If mixed in the proportion of one part in bulk of the former, and two parts of the latter gas, or more accurately, 85 parts by weight of oxigen gas, and 15 of hidrogen gas, and then exploded over water, the volume of the gases disappears, and the exploding tube in which they were contained, becomes completely filled with water, on account of the total vacuum which had been formed.

If the explosion be made in a close vessel, or over mercury, a quantity of water is always produced, equal in weight to the gases employed.

This water must be composed of the two gases; for it did not previously exist in the vessel, and no other substance besides the gases was introduced. Water then is composed of oxigen and hidrogen; and the combustion of hidrogen is nothing but the act of its combination with oxigen.

It has been with great plausibility conjectured that detonations in the air, or claps of thunder, are similar effects of the combustion of hidrogen and oxigen gas, and that the rain which falls so

copiously at the time of thunder-storms, is owing to a sudden formation of water in the atmosphere, from the rapid combustion of the hidrogen and oxigen gases fired by an electric spark.

The diminution of hidrogen and oxigen gases by their bases may also be shown in the following manner.

Experiment XI.

Fill a tall jar with oxigen gas, and fill also with hidrogen gas, a bladder furnished with a stop-cock, and with a long brass pipe like the letter S, and drawn out to a fine point. On pressing the bladder a stream of gas will issue from the pipe which may be set fire to and brought cautiously under the inverted jar of oxigen gas. By this intercourse, the stream of hidrogen gas will be burnt in a confined portion of oxigen gas; by continuing the combustion a sufficient time, the water will rise gradually within the jar. On the first impression of the heat, indeed, a small quantity of gas will escape from the jar, which will render it difficult to ascertain what degree of absorption actually takes place. But this loss may be prevented by using a jar, with a neck at the top, to which a compressed bladder is firmly tied. The expanded air instead of escaping through the water, will now enter the bladder at the top; and when the experiment is closed and the vessels have cooled, it may be ascertained by pressing out the gas from the bladder, what quantity of oxigen gas has been consumed. When this experiment is made with the substitution of common air for oxigen gas, a diminution takes place, but much less considerable, *viz.* not amounting to one-sixth of the original bulk of the gases.

Rationale...The disappearance of the gases depends on the union of their bases, which takes place during the state of ignition, and forms water, as has been noticed already.

NITROGEN GAS.

PART XVII.

SECT. I.

PROPERTIES OF NITROGEN GAS.

NITROGEN gas, or azotic gas as it is also called, is not possessed of any remarkable property capable of characterizing it; but is principally distinguished by certain negative qualities, namely: It is extremely hurtful to respiration, and quickly kills animals.* Plants thrive and even flourish in it. It has no sensible taste. It neither reddens blue vegetable colours, nor precipitates lime, or barytic-water. Its weight is to common air, as .985 to 1.000. No combustible substance burns in nitrogen gas; but it is capable of combustion in combination with oxigen gas when exposed to the action of the electric spark. It is not absorbable by water. It is capable of dissolving sulphur, phosphorus and charcoal in minute quantities. It unites to hidrogen under certain conditions, and constitutes with it ammonia. When united to oxigen in different proportions it produces atmospheric air, gazeous oxid of azote or nitrogen, nitrous gas, nitrous acid and nitric

* Hence the name *azote* which signifies "destructive to life" from *α* and *ζωη*.

acid. It is a component part of all animal substances, and communicates to them their most distinctive characters. It was discovered by Dr. Rutherford of Edinburgh.

Nitrogen gas has been found by Priestley in the Bath waters, and by Pearson in the Buxton waters.

METHODS OF OBTAINING NITROGEN GAS.

Nitrogen gas may be obtained by various means. For instance, it has been long since ascertained that air which has served the purposes of combustion and respiration, is no longer proper for these uses. Chemists have availed themselves of this circumstance in order to obtain nitrogen gas in the following manner.

1. Make a quantity of sulphuret of potash or sulphuret of iron into a paste with water, and place the mixture in a saucer or plate over water, on a stand raised above the fluid; then invert over it a jar or bell-glass, and allow this to stand for a day or two. The air contained in the bell-glass will gradually diminish, as will appear from the ascent of the water, until only about three fourths of its original bulk remain.

When no further diminution takes place the vessel containing the sulphuret must be removed, and the remaining air will be found to be nitrogen gas.

RATIONALE....The moistened sulphuret of potash has a great affinity to oxigen, it attracts and separates it from the atmospheric air, and the nitrogen gas is left behind; the sulphur is during the experiment converted into sulphuric acid, which unites to the alcali and forms sulphate of potash. The water with which the sulphuret is moistened likewise undergoes a decomposition, as shall be more fully proved in another place.

2. Nitrogen gas may likewise be obtained from fresh animal substances. For this purpose cut a piece of lean muscular flesh into small pieces, introduce them into a retort and pour over them

weak nitric acid. If the heat of a lamp not exceeding 80° Fahr. be then gently applied the gas will be speedily obtained.

RATIONALE....Animal substances are composed of nitrogen, carbon, hidrogen and oxigen. On adding nitric acid the equilibrium of the respective affinities is destroyed, the nitrogen gas becoming separated.

That the nitric acid does not furnish the nitrogen gas is obvious, from its saturating after its action as large a quantity of alcali as before, consequently it could not have suffered any alteration.

REMARK...The fibrous part of animal matter is that which affords the most nitrogen gas; next to this all the concretive parts, such as the clot of blood; next to that, albuminous matter, such as the serum and white of eggs; gelatinous substances afford the least.

3. Nitrogen gas may likewise be obtained by causing oxigenated muriatic acid gas to be received in a vessel containing liquid ammonia.

RATIONALE...Ammonia consists of hidrogen and nitrogen. The hidrogen of the ammonia unites to the oxigen of the oxigenated muriatic acid and forms water, heat is evolved, the nitrogen becomes free, and the oxigenated muriatic acid becomes converted into simple muriatic acid.

Other methods of obtaining nitrogen gas will be given in the next Part.

SECT. II.

EXPERIMENTAL PROOFS

OF

THE PROPERTIES OF NITROGEN GAS.

Experiment I.

Nitrogen gas is not absorbable by water.

TAKE a long glass tube divided into equal measures, which are distinguished by marks made with a diamond or file; send up into it any quantity of nitrogen gas; on agitating it strongly over water no absorption will take place, the volume of the air will not be sensibly diminished.

Experiment II.

Nitrogen gas does not exhibit signs of acidity.

Fill a receiver with pure nitrogen gas, and introduce therein a piece of litmus paper, or a small quantity of tincture of red cabbage, no change of colour will be produced in either of them, the gas therefore cannot be acid.

Experiment III.

Nitrogen gas does not maintain combustion, and is fatal to animal life.

This may be proved by plunging a lighted taper into a glass filled with this gas, the taper will be immediately extinguished.

If a small animal, such as a mouse or bird, be immersed in the gas, it instantly dies.

Experiment IV.

Nitrogen gas is capable of combustion with oxigen, at a high temperature.

Take a barometer tube, the diameter of which is about the sixth part of an inch. Shut one of its ends with a cork, through the middle of which passes a small wire, with a ball of metal at each end. Fill the tube with mercury and invert it into a bason of this fluid. Throw up into the tube as much of a mixture of 13 parts of nitrogen gas and 87 parts of oxigen gas, as will fill three inches. Through this gas, by means of the wire in the cork, pass a number of electric sparks; the volume of the gas gradually diminishes, and in its place will be found nitrous acid.

Experiment V.

A mixture of nitrogen gas and oxigen gas, produces artificial atmospheric air.

Introduce into a bell-glass filled with water, four parts of nitrogen gas and one of oxigen gas; after shaking the mixture well together, an air will be formed greatly resembling that of our atmosphere; for if a lighted taper or any other burning substance be plunged into this fluid, it will burn in the same manner as it does in atmospheric air; it may be breathed with safety, and animals confined in it will live as long as in an equal quantity of atmospheric air.

Remark...Though we are not capable of producing in this manner, an air absolutely the same as that of the atmosphere, the fault is not to be attributed to our ignorance of the quantity

and quality of the gazeous bases, but to a difference in their union; in the atmosphere the union of the two gases is a true chemical combination, but in our experiments the mass of the formed air is a mere mechanical mixture.

Experiment VI.

Nitrogen gas does not precipitate lime from lime-water.

This may be proved by putting a quantity of lime-water into a tube filled with the gas and shaking it. The transparency of the lime-water will not be injured.

ATMOSPHERIC AIR.

PART XVIII.

WHATEVER has been hitherto stated relative to the different kinds of aeriform fluids, is chiefly important, because the knowledge of them is necessary to enable us to comprehend the nature of that gazeous fluid in which we are plunged the moment we are born, and in which we exist. This fluid which surrounds the earth to a considerable, but unknown height above its surface, is called

THE ATMOSPHERE.

In treating of the different aeriform fluids which have hitherto been the subject of our consideration, it was necessary in some measure to anticipate the present, and to intimate that the air of our atmosphere is not, as was formerly supposed, a simple or homogeneous fluid, but that in reality it is composed of two distinct fluids, called oxigen gas and nitrogen gas.

Strictly speaking, the air of our atmosphere is however not so simple a substance as to be formed only of two ingredients. Besides the two substances of which it is composed, it contains a small portion of another gazeous fluid, called *carbonic acid.*

It is also well known that a large portion of water is generally contained in the atmosphere, besides a great variety of substances which are subject to evaporation, and which are capable of existing in an aeriform state at the usual temperature.

SECT. I.

MECHANICAL EXAMINATION

OF

ATMOSPHERIC AIR.

BY mechanical examination we would be understood to mean such properties as are connected with sensible changes of motion, and which indicate the presence and agency of moving or mechanical powers. They are therefore strictly the subject of mathematical discussion; admitting of measure, number, and direction; notions indeed purely mathematical. But as those mechanical properties characterise, or are peculiar *to all kinds* of elastic aeriform or gazeous fluids, no objection occurs to us against the propriety of considering them here briefly.

The mechanical properties of atmospheric air, are GRAVITY, ELASTICITY, INVISIBILITY, and DILATABILITY.

GRAVITY OF ATMOSPHERIC AIR.

EXPERIMENT I.

To prove the weight of the air, a pair of common bellows may serve; thus, for instance, if we stop the nozle and secure the valve-hole closely, having first blown or squeezed all the air out of them, we shall find that a considerable force is requisite for separating the boards. They are kept together by the pressure of the air which surrounds them, in the same manner as if they were immersed in water.

Experiment II.

In like manner, if we stop the end of a syringe, after its piston has been pressed down quite to the bottom, and then endeavour to draw it up, we shall find a considerable force necessary, *viz.* about 15 pounds for every square inch of the section of the syringe. Exerting this force we can draw up the piston and hold it there; but the moment we cease pulling, the piston rushes down again. We feel something as it were drawing in the piston, but it is solely the weight of the incumbent air pressing it; and this obtains in every position of the syringe; because the air is a fluid and presses in every direction; nay, it presses on the syringe as well as on the piston; for if the piston be suspended by its ring on a nail, it will require a weight to draw down the syringe, equal to that which is necessary to draw up the piston, and as soon as the syringe is freed from the weight it will spring up to its place again.

That the air presses equally in all directions becomes obvious from the following experiments:

Experiment III.

In a tall phial let an orifice be made about three inches from the bottom; stop this orifice. Through a cork in the neck of the phial, insert a long tube open at each end, and let the lower end be below the orifice in the side of the phial. The mouth of the phial being closed up about the tube, pour water into the tube till it is full. Upon opening the orifice, the water will be discharged, till its surface in the tube is level with the orifice; after which it will cease to flow, because the external lateral pressure of the air, balances the perpendicular pressure upon the water in the tube.

Experiment IV.

If a conical wine-glass be filled with water, and covered with a loose piece of paper; on inverting the glass the water will be kept from falling by the upward pressure of the air.

Experiment V.

If a vessel be perforated with small holes at the bottom, but closed at the top, the upward pressure of the air will keep water within the vessel, as will appear by successively stopping and unstopping a small hole in the top.

The pressure of the air may be shown by means of the Air-pump.

Experiment VI.

Let the air be exhausted from a glass receiver placed on the pump, the vessel will be held fast by the pressure of the external air.

Experiment VII.

Let a small receiver be placed under a larger one and both be exhausted; the larger will be held fast while the small one being protected from the pressure of the air may be easily moved.

Experiment VIII.

If the hand be placed upon a small open vessel, in such a manner as to close its upper orifice, it will be held down with great force, if the vessel be exhausted.

Experiment IX.

If the mouth of an open receiver be closely covered with a piece of bladder, and then exhausted, the super-incumbent air

will burst the bladder with a loud report. In a similar situation a thin plate of glass may be broken.

Experiment X.

If a glass bulb with a long neck filled with water be put inverted into a vessel of the same fluid, placed under a receiver, and the latter be exhausted, on re-admitting the air its pressure upon the surface of the water in the vessel, will cause the fluid to rise up in the bulb.

Experiment XI.

If on a plate, called a *transferrer*, the air be exhausted from a long receiver, and then water be admitted through a pipe by means of a stop-cock, the water will be pressed up and form a fountain.

Experiment XII.

If the air be exhausted from a vessel and by means of a cock kept so, and the vessel be weighed while it is empty, and again weighed when the air is re-admitted; the difference will be the weight of the quantity of air the vessel contains.

Experiment XIII.

Fill a glass tube, about three feet long, and closed at one end, with mercury; then insert the open end in a cup or vessel of the same fluid. The mercury in the tube will be kept suspended, by the pressure of the external air on the surface of that which is on the open cup: when this pressure is removed by placing them under a receiver, and exhausting it; the mercury in the tube will sink, and rise again on re-admitting the air.

On the gravity of the air depends the ascent of water in pumps, syphons, &c. and the phenomena of the barometer.

The weight of the air compresses all fluids and resists their dilatation; it opposes the evaporation of fluids, &c.

The gravity of the air resists the dilatation of the animal fluids; for the blood often bursts through the skin, or from the lungs, on the top of high mountains, occasioning hemorrhages, &c. because the air is there considerably lighter than near the level of the sea.

By the pressure of the air the sucking of animals, the art of cupping, and many other phenomena are explained, too numerous to be noticed here.

Thus the doctrine of the gravity and pressure of the air being established, by the most unexceptionable evidence; we are entitled to assume, *a priori*, all its legitimate consequences.

SPECIFIC WEIGHT OF ATMOSPHERIC AIR.

A bulk of atmospheric air that is equal to an English quart, when taken near the level of the sea, and at about 50° Fahr. weighs at a medium about 16 grains, and the same bulk of rain-water at the same temperature, weighs about 14621 grains. Hence rain-water is about 914 times specifically heavier than air.

The pressure of the air is equal to about 15 pounds troy on every square inch, and this pressure is the same in every direction. A square mile contains 27,878,400 square feet. The earth's surface in round numbers is 200,000,000 square miles, and therefore the pressure of the atmosphere circumfused about the whole surface of the earth is 12‴,043,468″,800,000′,000,000 pounds.

The surface of a middle sized man is about 14 square feet, he sustains therefore a weight of air, that is equal at a medium to about 30,240 pounds troy, or 24,882½ pounds avoirdupois nearly, or 1777 stone and 4 pounds, or 11 tons, 2 cwt. 18½ lbs.

Though our body supports such an enormous weight we need not wonder at the freedom with which we traverse this atmosphere. We see fish move with as great ease in a much more

dense and more ponderous fluid. We are not sensible of the weight of the air, on account of its being equally applied on every side, besides, that we have been accustomed to support it from our earliest infancy. Sensations to which we have at all times been habituated, are not felt; we can perceive no difference where we have no standard to judge of variations.

ELASTICITY OF ATMOSPHERIC AIR.

That the air is an elastic fluid, or capable of compression and expansion may be proved by a great number of experiments. In fact the elasticity or spring of the air produces the same effect as the pressure, because the pressure is equal to the compressing force; for if it were less, it is clear it would yield and be more compressed; were it greater, it would not be so much reduced; for action and re-action are always equal.

The air-gun, the effects of which are generally known, illustrates the elasticity of the air and shows the compression it is susceptible of.

A foot-ball or bladder filled with air, rebounds from any hard body.

The elasticity of the air is also proved by fish and other animals. The former have received from nature various means of action; among these are an air-bladder, which they contract or dilate at pleasure, and by this double property they ascend or descend in the water.

INVISIBILITY OF AIR.

Atmospheric air when confined in vessels is absolutely invisible, and cannot be distinguished from the glass which contains it. It owes this property to the ready passage it affords to the rays of light, which are refracted without being reflected; and it is therefore destitute of colour; though some philosophers have persuaded themselves that they discovered large masses of it to be

of a blue colour, as is the case in the sky, or in viewing extensive landscapes. But this is certainly a mistake; the blue colour is occasioned by the vapours which are always mixed with the air, and which have the property of reflecting the blue rays more copiously than any other.

It appears from the very accurate observations of Saussure, that the colour of the sky acquires a deeper shade in proportion as it is viewed from a more elevated situation.* Consequently at a certain height the blue will disappear altogether, and the sky appear *black*, that is to say it will reflect no light at all.

DILATABILITY OF AIR.

We have noticed already (page 70,) that if a flaccid or half-blown bladder be exposed to the action of caloric, the air will be dilated so as to burst the bladder.

Experiment I.

To the bottom of a hollow glsss-ball let an open bended tube be affixed. Let the lower part of the bended tube be filled with mercury; the external surface will be pressed by the weight of the atmosphere, and the air inclosed in the ball of the tube by means of the mercury will be equally pressed by the spring of the air within the vessel. If the ball be immersed in boiling water, the increased elasticity of the included air will raise the mercury in the tube.

Remark...The theory of the Mongolfiers depends on the rarefaction of the air. In this case a given volume of atmospheric air is rarefied by heat, and kept separated from the common mass, by a hollow vessel of cloth. This rarefied space may therefore be considered as consisting of a mass of air of greater levity than atmospheric air. It must therefore make an effort to rise in it.

* Journal de Physique, March 1777, and Saussure's Voyages dans les Alpes.

SECT. II.

CHEMICAL EXAMINATION

OF

ATMOSPHERIC AIR.

CHEMISTRY affords two general methods of investigating the constituent parts of bodies, Analysis and Synthesis; that both of these methods can be applied in the investigation of the nature of atmospheric air, we shall endeavour to prove.

From some ingenious experiments Lavoisier has demonstrated as stated already, that the air of our atmosphere is not a simple homogeneous fluid, but consists of two elastic aeriform bodies, possessing very different properties, one of which is capable of supporting combustion and animal life, called oxigen gas, and the other is destructive to animals and extinguishes fire, called nitrogen gas. The atmosphere contains some other gazeous fluids, or bodies capable of being dissolved or suspended in it, but in small quantities. Late experiments seem to have proved that a minute quantity of carbonic acid is always contained in the air, for alcalies become effervescent; strontia, barytic, and lime-waters acquire a pellicle on being exposed a sufficient time to the action of the air, even upon the highest mountains. Water is likewise always found in the atmosphere, but the quantity of these matters is extremely minute; and experiments are still wanting to prove satisfactorily that carbonic acid gas and water are always and every where present in our atmosphere.

The former constituents must therefore be considered as the two substances of which atmospheric air is composed.

Since the nitrogen gas of the atmospheric air cannot be separated by any substance with which chemists are acquainted, the analysis of air can only be attempted by exposing it to the action of those bodies which have the property of abstracting its oxigen. The oxigen gas being separated, the nitrogen is left behind, and the proportion of oxigen may be ascertained by the diminution of bulk, which once known, it is easy to determine the exact relative quantity of the component parts.

ANALYSIS OF ATMOSPHERIC AIR.

Experiment I.

Fasten a straight piece of wax taper, about four inches long upon a cork, then take an empty wine bottle and hold it by the neck, in an inverted position; light the taper and introduce it quickly into the mouth of the bottle; push in the cork in order to prevent the entrance of any air from without. The flame of the taper will burn well at first, but in a few minutes it will contract, grow dim, and at last be extinguished.

If now the taper be quickly withdrawn, the mouth of the bottle being closed with the thumb, and the taper lighted again and introduced into the bottle, it will be immediately extinguished.

On introducing the bottle in an inverted position into a bason of water, and then withdrawing the cork, the water will ascend into the bottle and fill the place of the air which has been lost.

The following experiment will farther illustrate this fact.

Experiment II.

Take a florence flask, holding about a pint, put into it three or four grains of phosphorus, and cork it air-tight. Having

done this heat it gradually over a lamp. As soon as the phosphorus has been heated to a certain degree it takes fire, burning with a flame and a dense white smoke; but as it soon ceases to burn, heat the vessel again, after it has cooled, to try if any more combustion will take place; lastly, let the flask cool.

If the vessel was perfectly dry, the inside of it will be lined with a white coating, but if it was moist this coating will be dissolved into a fluid, (phosphoric acid.)

After every thing has returned to its former temperature, plunge the flask inverted under water and draw out the cork; the water will ascend in it, hence a portion of the air it contained *has disappeared.*

The water which has risen shows what quantity of air has been lost, if its cubic contents be compared with that of the whole vessel. The portion of air thus vanished will in general amount to about one fifth of the whole that had been submitted to the experiment.

If the flask, after the phosphorus was inclosed in it, be accurately weighed, and again after the combustion has taken place no difference of weight will be found.

The water forced up into the vessel changes the blue tincture of cabbage-juice to red; an evident proof of the presence of an acid.

The remaining air is unfit for burning phosphorus or other bodies; animals are likewise suffocated in it.

RATIONALE...Phosphorus is a simple body; on being heated it analyses the atmospheric air, that is to say, the equilibrium of the affinity subsisting between the compound parts of the air, namely, the oxigen and the nitrogen is broken, on account of the phosphorus having a greater attraction for the oxigen than the nitrogen has, it therefore unites to it, and becomes by this addition converted into an acid, called phosphoric acid: the other part of the atmosphere remains behind. The light and

heat which are liberated during the combustion arise both from the oxigen gas, and the phosphorus.

Experiment III.

Take a piece of lead or any other material considerably heavier than water, fasten into it perpendicularly metal wires of different lengths; affix tapers to the extremities of these wires, and place the stand in the middle of a flat dish or bason half filled with water. Then light the tapers (which should differ in height five or six inches) and cover the whole with a tall cylindrical glass receiver. The tapers will burn during the first few minutes all alike, but after some time the highest one will assume a blue colour, and at last be extinguished, and the water in the dish will begin to rise; the next taper in height will then burn dull and go out, and the others will be extinguished in succession. The water will rise at the same time considerably up into the glass.

Rationale...The philosophy of this experiment is analogous to the former. The burning bodies effect in the confined quantity of atmospheric air, a real analysis. They absorb the oxigen it contains and divest it of this principle, leaving the nitrogen gas behind. Combustion therefore consists in the absorption of oxigen gas, by a combustible body, the basis of the oxigen being absorbed and the caloric set at liberty

SECT. III.

EUDIOMETRY,

OR

METHODS OF ASCERTAINING THE PURITY OF ATMOSPHERIC AIR.

No sooner was the composition of the atmosphere known, than it became an enquiry of importance to find out a method of ascertaining with facility and precision, the relative quantity of oxigen gas contained in a given bulk of atmospheric air.

The instruments in which the oxigen gas of a determined quantity of air was ascertained, received the name of EUDIOMETERS, because they were considered as measurers of the purity of air. They are however more properly called OXIMETERS.

The eudiometers proposed by different chemists, are the following:

1. PRIESTLEY's EUDIOMETER.

The first eudiometer was made in consequence of Dr. Priestley's discovery, that when nitrous gas is mixed with atmospheric air over water, the bulk of the mixture diminishes rapidly, in consequence of the combination of the gas with the oxigen of the air, and the absorption of the nitric acid thus formed by the water.

When nitrous gas is mixed with nitrogen gas, no diminution takes place; but when it is mixed with oxigen gas in proper proportions, the absorption is complete. Hence it is evident, that in all cases of a mixture of these two gases, the diminution will be proportional to the quantity of the oxigen. Of course it will indicate the proportion of oxigen in air; and by mixing it with different portions of air, it will indicate the different quantities of oxigen which they contain, provided the component parts of air be susceptible of variation.

Dr. Priestley's method was to mix together equal bulks of air and nitrous gas in a low jar, and then transfer the mixture into a narrow graduated glass tube about three feet long, in order to measure the diminution of bulk. He expressed this diminution by the number of hundredth parts remaining. Thus, suppose he had mixed together equal parts of nitrous gas and air, and that the sum total was 200 (or 2.00): suppose the residuum when measured in the graduated tube to amount to 104 (or 1.04), and of course that 96 parts of the whole had disappeared, he denoted the purity of the air thus tried by 104.

REMARK...This method of analysing air by means of nitrous gas is liable to many errors. For the water over which the experiment is made, may contain more or less carbonic acid, atmospheric air, or other heterogeneous substance. The nitrous gas is not always of the same composition, and is partly absorbed by the nitrous acid which is formed; the figure of the vessel and many other circumstances are capable of occasioning considerable differences in the results.

Fontana, Cavendish, Ladriani, Magellan, Von Humbolt, and Dr. Falconer have made series of laborious experiments to bring the test of nitrous gas to a state of complete accuracy; but notwithstanding the exertions of these philosophers the methods of analysing air by means of nitrous gas are liable to so many anomalies that we think it unnecessary to give a particular description of the different instruments invented by them.

2. SCHEELE's EUDIOMETER

Is merely a graduated glass cylinder, containing a given quantity of air, exposed to a mixture of iron filings and sulphur formed into a paste with water. The substances may be made use of in the following manner:

Make a quantity of sulphur in powder, and iron filings, into a paste with water, and place the mixture in a saucer or plate, over water, on a stand raised above the fluid; then invert over it a graduated bell-glass, and allow this to stand for a day or two. The air contained in the bell-glass will gradually diminish, as will appear from the ascent of the water.

When no further diminution takes place, the vessel containing the sulphuret must be removed, and the remaining air will be found to be nitrogen gas, which was contained in that quantity of atmospheric air.

RATIONALE....The moistened sulphuret of iron has a great affinity to oxigen, it attracts and separates it from the atmospheric air, and the nitrogen gas is left behind; the sulphur during the experiment is converted into sulphuric acid, which unites to the alcali and forms sulphate of potash.

The air which is exposed to moistened iron and sulphur gradually becomes diminished on account of its oxigen combining with a portion of the sulphur which becomes converted into sulphuric acid, and its nitrogen remains behind. The quantity of oxigen contained in the air examined becomes thus obvious, by the diminution of bulk, which the volume of air submitted to examination has undergone.

REMARK...The only error to which this method is liable, is that the sulphuric acid which is formed acts on the iron and produces hidrogen gas, which joins to the nitrogen remaining after the absorption, and occasions an incorrect result; and hence it is that the absorption amounts in general to 0.27 parts, although the true quantity of oxigen is no more than from 0.21 to 0.22.

3. DE MARTI's EUDIOMETER.

De Marti obviated the errors to which the method of Scheele was liable. He availed himself for that purpose of a hidrogenated sulphuret, formed by boiling sulphur and liquid potash, or lime-water together. These substances when newly prepared, have the property of absorbing a minute portion of nitrogen gas; but they lose this property when saturated with that gas, which is easily effected by agitating them for a few minutes in contact with a small portion of atmospheric air.

The apparatus is merely a glass tube, ten inches long, and rather less than half an inch in diameter, open at one end, and hermetically sealed at the other. The close end is divided into 100 equal parts, having an interval of one line between each division. The use of this tube is to measure the portion of air to be employed in the experiment. The tube is filled with water; and by allowing the water to run out gradually while the tube is inverted, and the open end kept shut with the finger, the graduated part is exactly filled with air. These hundred parts of air are introduced into a glass bottle filled with liquid sulphuret of lime previously saturated with nitrogen gas, and capable of holding from two to four times the bulk of the air introduced. The bottle is then to be closed with a ground glass stopper, and agitated for five minutes. After this the stopper is to be withdrawn while the mouth of the phial is under water; and for the greater accuracy, it may be closed and agitated again. Lastly, the air is to be again transferred to the graduated glass tube, in order to ascertain the diminution of its bulk.*

4. HUMBOLT's EUDIOMETER

Consists in decomposing a definite quantity of atmospheric air by means of the combustion of phosphorus, after which the portion of gas which remains must be measured.

* Journ. de Phys. LII. 176.

Take a glass cylinder closed at the top, and whose capacity must be measured into sufficiently small portions by a graduated scale fixed on it. If the instrument be destined solely for examining atmospheric air, it will be sufficient to apply the scale from the orifice of the cylinder down to about half its length, or to sketch that scale on a slip of paper pasted on the outside of the tube, and to varnish it over with a transparent varnish.

This half of the eudiometrical tube is divided into fifty equidistant parts, which in this case indicate hundredth parts of the whole capacity of the instrument.

Into this vessel full of atmospheric air put a piece of dry phosphorus (one grain to every twelve cubic inches) close it air-tight and heat it gradually, first the sides near the bottom and afterwards the bottom itself. The phosphorus will take fire and burn rapidly. After every thing is cold, invert the mouth of the eudiometer-tube into a bason of water or mercury, and withdraw the cork. The water will ascend in proportion to the loss of oxigen gas the air has sustained, and thus its quantity may be ascertained.

Analogous to this is

5. SEGUIN's EUDIOMETER,

Which consists of a glass tube of about one inch in diameter, and eight or ten inches high, closed at the upper extremity. It is filled with mercury and kept inverted in this fluid in the mercurial trough. A small bit of phosphorus is introduced into it, which on account of its specific gravity being less than that of mercury, will rise up in it to the top. The phosphorus is then melted by means of a red-hot poker, or burning coal applied to the outside of the tube. When the phosphorus is liquified, small portions of air destined to be examined, and which have been previously measured in a vessel graduated to the cubic inch or into grains, are introduced into the tube. As soon as the air which

is sent up reaches the phosphorus, a combustion will take place and the mercury will rise again. The combustion continues till the end of the operation; but for the greater exactness, Mr. Seguin directs the residuum to be heated strongly. When cold, it is introduced into a small vessel, whose capacity has been ascertained at the same time as that of the preceding. The difference of the two volumes gives the quantity of the oxigen gas contained in the air subjected to examination.

Remark...The objection to which this eudiometer is liable will be noticed in the next, which is said to be an improvement of this.

6. BERTHOLET's EUDIOMETER.

Instead of the rapid combustion of phosphorus, Bertholet has substituted its spontaneous combustion which absorbs the oxigen of atmospheric air completely, and when the quantity of air operated on is small, the process is accomplished in a short time.

Bertholet's apparatus consists of a narrow graduated glass tube, containing the air to be examined, into which is introduced a cylinder or stick of phosphorus supported upon a glass rod, while the tube stands inverted in water. The phosphorus should be nearly as long as the tube. Immediately after the introduction of the phosphorus, white vapours are formed which fill the tube, these vapours gradually descend and become absorbed by the water. When no more white vapours appear, the process is at an end, for all the oxigen gas which was present in the confined quantity of air, has united with the phosphorus; the residuum is the quantity of nitrogen of the air submitted to examination.

Remark...This eudiometer though excellent of the kind, is nevertheless not absolutely to be depended upon; for as soon as the absorption of oxigen is completed, the nitrogen gas exercises an action upon the phosphorus and thus its bulk becomes increased. It has been ascertained that the volume of nitrogen gas is increased to $\frac{1}{40}$ part; consequently the bulk of the re-

diuum diminished by $\frac{1}{40}$ gives us the bulk of the nitrogen gas of the air examined; which bulk subtracted from the original mass of air, gives us the proportion of oxigen gas contained in it. The same allowance must be made in the eudiometer of Seguin.

7. DAVY's EUDIOMETER.

Until very lately the preceding processes were the methods of determining the relative proportions of the two gases which compose our atmosphere.

Some of these methods though very ingenious are so extremely slow in their action, that it is difficult to ascertain the precise time at which the operation ceases. Others have frequently involved inaccuracies, not easily removed.

The eudiometer we are now going to describe, is not only free from these objections, but the result it offers is always constant, it requires little address, and is very expeditious; the apparatus is portable, simple and convenient.

Take a small glass tube graduated into one hundred equi-distant parts; fill this tube with the air to be examined, and plunge it into a bottle or any other convenient vessel, containing a concentrated solution of green muriate or sulphate of iron, strongly impregnated with nitrous gas. All that is necessary to be done is to move the tube in the solution a little backwards and forwards; under these circumstances the oxigen gas contained in the air will be rapidly absorbed, and condensed by the nitrous gas in the solution, in the form of nitrous acid.

N. B. The state of the greatest absorption must be marked, as the mixture afterwards emits a little gas which would alter the result.

This circumstance depends upon the slow decomposition of the nitrous acid (formed during the experiment), by the green oxid of iron, and the consequent production of a small quantity of aeriform fluid (chiefly nitrous gas); which having no affi-

nity with the red muriate, or sulphate of iron, produced by the combination of oxigen, is gradually evolved, and mingled with the residual nitrogen gas.

The impregnated solution with green muriate is more rapid in its operation than the solution with green sulphate. In cases when these salts cannot be obtained in a state of absolute purity, the common sulphate of iron of commerce may be employed. One cubic inch of moderately strong impregnated solution, is capable of absorbing five or six cubic inches of oxigen, in common processes; but the same quantity must never be employed for more than one experiment.

GENERAL REMARKS.

In all these different methods of analysing air, it is necessary to operate on air of a determinate density, and to take care that the residuum be neither more condensed nor dilated than the air was when first operated on. If these things are not attended to, no dependance whatever can be placed upon the result of the experiments, how carefully soever they may have been performed. It is therefore necessary to place the air before and after the examination into water of the same temperature. If this and several other little circumstances have been attended to, for instance a change in the height of the barometer, &c. we find that air is composed of 0.22 of oxigen gas, and 0.78 of nitrogen gas by bulk. But as the weight of these two gases is not exactly the same, the proportion of the component parts by weight will differ a little; for as the specific gravity of oxigen gas is to that of nitrogen gas as 135 : 115, it follows that 100 parts of air are composed *by weight* of about

74 nitrogen gas
26 oxigen gas

100

The air of this metropolis examined by means of Davy's eudiometer, was found in all the different seasons of the year to con-

tain 0.21 of oxigen, and the same was the case with air taken at Islington, and Highgate; in the solitary cells in Cold-bath-fields prison, and on the River Thames. But the quantity of water contained in a given bulk of air from these places differed considerably.

Having thus ascertained the nature and the proportion of the component parts of air, it remains only to enquire in what manner these component parts are united. Are they merely mixed together mechanically, or are they combined chemically? Is air a mechanical mixture or a chemical compound? Philosophers seem at first to have adopted the former of these opinions, if we except Scheele, who always considered air as a chemical compound. But the supposition that air is a mechanical mixture, by no means agrees with the phenomena which it exhibits. If the two gases were only mixed together, as their specific gravity is different, it is scarcely possible that they would be uniformly mixed in every part of the atmophere. Since therefore air is in *all places* composed of the same ingredients, exactly in the same proportions, it follows that its component parts are not only mixed, but actually combined. When substances differing in specific gravity combine together, the specific gravity of the compound is usually greater than the mean. This holds good also with respect to air. The specific gravity, by calculation, amounts only to 0.00119, whereas it actually is 0.0012.

We must therefore consider air as a chemical compound. Hence the reason that it is in all cases the same, notwithstanding the numerous decomposing processes, to which it is subjected. The breathing of animals, combustion, and a thousand other operations, are constantly abstracting its oxigen, and decomposing it. The air thus decomposed or vitiated, no doubt ascends in the atmosphere, and is again, by some unknown process re-converted into atmospheric air. But the nature of these changes is at present concealed under an impenetrable veil.

CARBONIC ACID GAS.

PART XIX.

SECT. I.

CARBONIC acid gas is the first elastic aeriform fluid that was known. We find that the ancients were in some measure acquainted with it. Van Helmont called it the gas of Must, or of the vintage, or *gas sylvestre*.

We are indebted to Dr. Black of Edinburgh for the knowledge of some of the most remarkable properties of this fluid. In the year 1755 he discovered the affinity between this gas and alcalies: and Bergman, in 1772, proved that it was an acid.

PROPERTIES OF CARBONIC ACID GAS.

Carbonic acid gas is invisible. It extinguishes flame. It is fatal to animal life. It exerts powerful effects on living vegetables. Its taste is pungent and acid. Its energy, as an acid, is but feeble, although distinct and certain. Neither light, or caloric seem to produce any distinct effect upon it, except that the latter dilates it. It mixes without combining with oxigen gas. It unites with water slowly. These two fluids, after considerable agitation, at last combine, and form a sub-acid

fluid. The colder the water and the greater the pressure applied, the more carbonic acid gas will be absorbed. The water impregnated with it sparkles upon agitation; it has a pungent, acidulous taste, and reddens tincture of litmus. Heat again disengages the gas from the water. This gas precipitates lime, strontia, and barytes, from their solutions in water. It is greedily attracted by all the alcalies. It undergoes no alteration by light. Its specific weight is to that of atmospheric air as 1500 to 1000. It may be poured out of one vessel into another. It is not acted upon by oxigen, nor is it altered by any of the simple combustible bodies at common temperatures; but phosphorus, iron, and lime are capable of decomposing it, when assisted by heat.

METHODS OF OBTAINING CARBONIC ACID GAS.

Of all the gases, carbonic acid gas is that perhaps, which is diffused in the greatest abundance throughout nature. It is found in three different states:...1*st*, In that of gas; 2*dly*, In that of mixture; and 3*dly*, In that of combination. The various processes for obtaining it are the following:

1. Put into a common gas-bottle or retort, a little marble, chalk, or lime-stone, and pour on it sulphuric acid, diluted with about six times its weight of water, an effervescence will ensue, and carbonic acid gas will be liberated, which those who have an opportunity may collect over mercury; but a mercurial apparatus is not absolutely necessary, since the gas may be collected over water, if it is to be used immediately when procured.

RATIONALE...In this instance the carbonic acid is disengaged from the state of combination, and reduced to the aeriform state of gas. The marble, lime-stone, or chalk consists of this acid and lime; on presenting to it sulphuric acid, a decomposition takes place, the sulphuric acid has a greater affinity to the lime than the carbonic acid has, it therefore unites to it, and forms sulphate of lime, disengaging at the same time the car-

bonic acid in the state of gas, at the temperature of our atmosphere.

Remark...Carbonic acid gas may in this manner be disengaged from all its combinations with alcalies; by using indifferently any other dense acid, possessing a superior affinity to the alcali in the common acceptation of the word.

2. It may likewise be obtained from the same substances by the action of caloric.

For this purpose reduce marble or chalk to powder, introduce it into a gun-barrel, which must be placed across a furnace, adapt a bent tube to its lower extremity and insert it below a receiver in the pneumatic apparatus. Maintain a strong heat till the barrel is brought to a state of ignition, and at that temperature carbonic acid gas will be liberated in abundance.

Rationale...In this case a decomposition of the marble or carbonate of lime takes place on account of the action of caloric, which at a high temperature breaks the affinity of the carbonic acid and lime; it unites with the first, and leaves the lime behind in that state which is generally called quick-lime.

3. Carbonic acid gas may also be obtained by burning charcoal in oxigen gas. We have already mentioned this, but we shall here give directions how it is best effected.

Take a bell-glass, filled with oxigen gas, resting inverted in a bason of mercury; pass up into it some bits of new-made charcoal, with some touch-paper affixed to them; set fire to them by means of a lens collecting the sun's rays, and carbonic acid will be produced by the combustion of the charcoal.

The rationale of this experiment has been given page 190.

Carbonic acid gas is often found occupying the lower parts of mines, caverns, tombs, and such other subterraneous places as contain materials for producing it. It is called choke, or chalk-damp. The grotto del Cane, near Naples, has long been famous for the quantity of carbonic acid gas produced there, which runs out at the opening like a stream of water. The quantity of carbonic acid gas generated in this cavern is so great, that a dog or

any other animal is immediately killed if his nose be thrust into it.

The carbonic acid, existing naturally in the state of gas, may be collected by filling bottles with water and emptying them into the atmosphere of this gas; the gas takes the place of the water and fills the bottles, which must then be corked.

Carbonic acid gas is likewise formed during fermentation; on account of its great weight it occupies the apparently empty space, or upper part of the vessel in which the fermenting process is going on. It may in this case be collected in a manner similar to that above.

Carbonic acid gas is also obtained during the reduction of metallic oxids, and during the deflagration of nitrates with combustible bodies, as shall be noticed in another part of this work.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF CARBONIC ACID GAS.

Experiment I.

Carbonic acid gas is unfit for combustion.

To prove this, set a vessel filled with this gas, with its mouth upwards, and let down a lighted candle; the candle will be immediately extinguished, and the smoke remaining in the gas will render its surface visible, which by agitation may be thrown into undulating waves.

The following experiment will show this property in a pleasing manner.

Experiment II.

Take three glass tubes, of equal heights, and fill the first with atmospheric air, the second with carbonic acid gas, and the third with oxigen gas; plunge successively and with swiftness, a lighted taper into these three tubes, first into that containing atmospheric air, then into the tube filled with carbonic acid gas, and lastly into that filled with oxigen gas. In the tube filled with atmospheric air, the taper will burn with its usual brightness; in that filled with carbonic acid gas, the flame will be sud-

denly extinguished, but the glowing wick will be re-lighted in the tube containing oxigen gas, and burn with a dazzling splendor.

Rationale...This experiment confirms a fact already established; namely, that oxigen gas is much fitter for combustion than atmospheric air; and is also a most complete proof that carbonic acid gas extinguishes light.

Remark...This property of carbonic acid gas may be advantageously made use of to learn whether the air in a newly sunk well, in subterraneous caverns, pits, mines, vaults, cellars, and the like, may be approached without danger.

Experiment III.

Carbonic acid gas is fatal to animal life.

Put a mouse or other small animal into a vessel filled with this gas, and cover the vessel to prevent the contact of atmospheric air. The animal will die in a minute or two.

Remark...It is this gas which has produced so many fatal accidents, at the opening of cellars or vaults, in which wine, cyder, or beer has been suffered to ferment.

The famous lake of Averno, where Virgil placed the entrance of Hell, yields so large a quantity of carbonic acid gas, that birds cannot fly close over it with impunity.

Experiment IV.

Carbonic acid gas is heavier than atmospheric air.

Let a long glass tube proceeding from a gas-bottle in which carbonic acid gas is disengaged, be twice bent at right angles. Let the open end of the longest leg reach to the bottom of a jar, perfectly dry within, and standing with its mouth uppermost. The carbonic acid disengaged will expel the atmospheric air from the jar, on account of its greater specific gravity. When the

jar is filled with the gas, (which may be known by a lighted candle being instantly extinguished in it a little below the brim,) take another jar of rather a smaller size, and place at the bottom of it a lighted taper or a small animal, and pour the invisible contents of the first jar into the second, (in the same manner as if water was poured) the candle will be immediately extinguished, or the animal will die; though the eye is incapable of perceiving any thing poured upon them capable of producing this effect.

Experiment V.

Carbonic acid gas is absorbable by water.

Fill a jar partly with this gas, and let it stand for some hours over water, an absorption will gradually take place, till at last none of the gas remains. If this be repeated, with this difference that the jar be shaken strongly, a very rapid diminution will take place.

Remark...Water may be charged with upwards of three times its own bulk of carbonic acid gas, if pressure be applied. The water thus impregnated has a very brisk and pleasant taste. Various kinds of apparatus are employed for this purpose. A machine has been invented by Dr. Nooth, and improved by Parker and Magellan, which is convenient and ingenious; but it is impossible to impregnate water by its means with more than half its own bulk of carbonic acid gas. The valve of this machine is the most defective, and renders it extremely apt to break. For the capillary tube does not admit the air through it, unless there be a considerable quantity condensed in the lower vessel, and the condensation is apt to burst the vessel. Other apparatus, more simple, have been invented by different persons, descriptions of which may be found in Scherer's Journal der Chimie; in the Transactions of the Manchester Philosophical Society; and in Bouillon La Grange's Manual of Chemistry, vol. I. page 93.

Cyder, perry, ale, champagne, &c. owe their briskness to the carbonic acid gas which they contain, and which becomes rapidly disengaged in order to assume the gazeous form, on removing the cork of the bottle; it is this also which produces froth, &c.

Experiment VI.

Carbonic acid gas when combined with water possesses acid properties.

This may be shown by dipping into water saturated with carbonic acid gas, a piece of litmus paper, or by mixing with it about an equal quantity of infusion of litmus. The blue colour of the paper or infusion will be changed to red.

Experiment VII.

Carbonic acid gas precipitates lime, barytic, and strontia water.

Let the stream of carbonic acid gas, as it proceeds from the disengaging vessel, pass into either of these solutions, the fluid, though perfectly transparent before, will instantly grow turbid, and carbonate of lime, barytes, or strontia will be formed.

If equal measures of water impregnated with carbonic acid gas, and either of the above solutions be mixed, a similar effect will be produced.

Experiment VIII.

Carbonic acid gas exerts powerful effects on living vegetables.

Water impregnated with carbonic acid gas proves highly nutritive, when applied to the roots of plants. But on the con-

trary, carbonic acid gas applied as an atmosphere, by confining living vegetables in it, proves injurious to the health of the plants especially in the shade.

This may be proved by confining a small plant in a vessel filled with the gas. The plant will soon decay and die.

RATIONALE...In the first case, where water is present, the carbonic acid is decomposed, the carbonaceous principle fixes itself into the vegetable, becoming a component part of it, the oxigen which held the carbon in solution is therefore disengaged in a gazeous state. In the latter instance no such effect takes place.

EXPERIMENT IX.

Carbonic acid gas is rapidly absorbed by alcalies.

Fill a tube with this gas over water, and when full invert it in a cup containing a concentrated solution of potash, or any other alcali, the solution will rise in the tube, and if the gas be very pure will fill it entirely.

RATIONALE...This absorption of the gas, is owing to the alcali uniting with the carbonic acid gas, and forming with it a saline compound, called carbonate of potash.

LIGHT CARBONATED HIDROGEN GAS.

PART XX.

SECT. I.

It was mentioned before that hidrogen gas has the property of dissolving various substances in minute quantities, such as carbon, sulphur, phosphorus, &c. The nature of the gas now under consideration furnishes an instance of this kind. Light carbonated hidrogen gas is hidrogen gas holding charcoal in solution. There are several combinations of this kind of gas obtained by different processes, which differ in their properties, and in the proportion of their constituent principles.

PROPERTIES OF LIGHT CARBONATED HIDROGEN GAS.

Light carbonated hidrogen gas has a fetid odour. It is neither absorbed nor altered by water. It is inflammable and burns with a denser and deeper coloured flame than hidrogen gas. It is unalterable by acids or alcalies, and by water. Its specific

gravity is greater than that of hidrogen gas, or that of common air. Its combustion with a due proportion of oxigen gas is productive of water and carbonic acid. When passed through melted sulphur, it becomes converted into sulphurated hidrogen gas, and charcoal is deposited. Electrization dilates it permanently to a little more than twice its original bulk. The air thus expanded requires a greater quantity of oxigen to decompose it, than the same quantity of gas not dilated by electricity; 100 cubic inches of pure carbonated hidrogen gas weigh from 16 to 21 grains.

METHODS OF OBTAINING LIGHT CARBONATED HIDROGEN GAS.

Light carbonated hidrogen gas may be obtained from animal, vegetable, or mineral substances. Nature produces it ready formed in marshes and ditches, on the surface of putrid water, in burying places, common sewers, and in those situations where putrid animal and vegetable matters are accumulated. It is also generated in the intestinal canal of living animals.

1. Light carbonated hidrogen gas may be plentifully procured from most stagnant waters: to do this fill a wide-mouthed bottle with the water, and keep it inverted therein with a funnel in its neck, then with a stick stir the mud at the bottom just under the funnel in the bottle, so as to let the bubbles of air which rise from the mud enter into the bottle; when by thus stirring the mud in various places, and catching the air in the bottle, it is filled, it must be corked under water.

2. It may be also obtained during the distillation of animal and vegetable matters. For instance,

Let shavings of wood or saw-dust, be put into a retort, and begin the distillation with a gentle heat, increasing it gradually till the retort becomes red-hot; a great quantity of gas will be liberated which may be caught over water. On examining this gas, it will be found to consist of carbonic acid gas and carbo-

nated hidrogen gas. In order to obtain the latter in a state of purity, the whole must be mixed with lime-water or with a caustic alcaline solution. The carbonic acid gas will be absorbed and the carbonated hidrogen gas left behind in a pure state.

RATIONALE...The production of this gas in this manner is the result of a partial analysis of the wood. It proves that wood contains solid hidrogen, carbon and oxigen. When the intensity of the heat has reached a certain degree, a part of the charcoal unites with part of the oxigen and produces carbonic acid, which by means of caloric is melted into the gazeous state and forms carbonic acid gas; at the same time a part of the hidrogen of the wood combines with another portion of carbon and caloric, and forms carbonated hidrogen gas.

REMARK...The flame of burning wood, &c. is the inflamed carbonated hidrogen gas, liberated on the application of caloric to such bodies.

3. Charcoal is in general made use of for obtaining light carbonated hidrogen gas. For this purpose put some moistened charcoal into an earthen retort, apply heat, and increase it till the retort becomes ignited; gas will be evolved, consisting partly of carbonic acid gas, and partly of light carbonated hidrogen gas, which may be separated as before.

RATIONALE...In this case a decomposition of the water takes place, by means of the charcoal. The oxigen forsakes its hidrogen and unites to part of the charcoal at this temperature, and forms carbonic acid gas, in conjunction with caloric; the liberated hidrogen assisted by caloric, dissolves another portion of the charcoal, and forms with it light carbonated hidrogen gas.

4. Light carbonated hidrogen gas may be formed in a direct manner by dissolving charcoal in hidrogen gas. This may be effected by directing the rays of the sun collected in the focus of a mirror, upon a small piece of charcoal placed on mercury, in a receiver filled with hidrogen gas.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF LIGHT CARBONATED HIDROGEN GAS.

Experiment I.

Light carbonated hidrogen gas is inflammable.

THIS may be shown by filling a tumbler or any wide-mouthed vessel with this gas, and setting fire to it, by means of a lighted taper. It may likewise be shown by burning it in the manner directed for burning hidrogen gas. The colour of the flame of this gas is of a deeper blue than that of hidrogen gas.

Experiment II.

Light carbonated hidrogen gas is heavier than hidrogen gas.

Soap bubbles blown with it do not ascend like those filled with pure hidrogen gas, but descend like those filled with common air. A jar filled with carbonated hidrogen gas, held inverted for a few minutes exchanges its contents for common air.

Experiment III.

Decomposition of light carbonated hidrogen gas, by means of oxigen gas.

Mr. Cruikshank found (Nicholson's Journal, April 1801) that six measures of carbonated hidrogen gas obtained from moistened charcoal, when mixed with four of pure oxigen gas, over mer-

cury exploded violently by the electric spark, and became augmented to $12\frac{1}{2}$ measures, or that there was an increase of $2\frac{1}{2}$ measures nearly. On admitting lime-water the volume diminished rather more than two measures; the residue amounted to $10\frac{1}{4}$, on which nitrous gas had no effect. Two measures of the residuary gas fired with one of oxigen, became reduced to one, which was carbonic acid gas. Hence the whole residuary gas would require about $5\frac{1}{4}$ measures of oxigen to saturate it, and produce 5 measures of carbonic acid gas.

Experiment IV.

Decomposition of light carbonated hidrogen gas, by means of oxigenated muriatic acid gas.

The effects of the oxigenated muriatic acid gas upon all the hidro-carbonates is remarkable. Mr. Cruikshank observed, that if the pure oxigenated muriatic acid gas, be mixed with these kinds of gases over water, although no action should be perceptible at first, yet in twenty-four hours a complete decomposition and change of principles takes place.

For instance, introduce into a bottle filled with and inverted over water, one measure of pure light carbonated hidrogen gas well washed, mixed with two measures of fresh prepared pure oxigenated muriatic acid gas. On the first contact of the oxigenated muriatic acid gas a white cloud and some diminution will be perceived, which will soon cease. The bottle must then be stopped and suffered to remain inverted in water for about twenty-four hours. If the bottle be then uncorked under water, this fluid will instantly ascend into it, and the gas will occupy about .43 parts of a measure, the diminution being 2.57 measures. On mixing the residuary gas with lime water .09 parts more become absorbed.

Rationale...The results obtained in this experiment with the pure light carbonated hidrogen gas, are very easily understood; for it is evident that the oxigenated muriatic acid gas gives out its excess of oxigen to the carbon and hidrogen, of the inflammable gas from a superior affinity; in consequence of which we have no less than four new compounds. Part of the oxigen of the oxigenated muriatic acid gas joins to the hidrogen of the carbonated hidrogen gas, and forms water; another part unites to the charcoal and produces carbonic acid gas; a still less quantity combines with another portion of charcoal, and forms gazeous oxid of carbon, and the oxigenated muriatic acid gas, by thus losing its excess of oxigen, becomes converted into simple muriatic acid gas.

Remark...According to Mr. Cruikshank's experiments 100 cubic inches of light carbonated hidrogen gas obtained from wetted charcoal, weighed 14.5 grains; they required 66 cubic inches (22.4 grains) of oxigen to saturate them. The compound yielded 40 cubic inches (19 grains) carbonic acid and nine grains of water. Hence this gas consists of nearly 4 of carbon, 1.3 of hidrogen, and 9 of water.

HEAVY CARBONATED HIDROGEN GAS.

PART XXI.

SECT. I.

THIS gas was first brought into notice by a society of Dutch chemists, consisting of Deiman, Troostwyk, Bond, and Laurenburgh. They observed in this gas the particular property, that when it was combined with oxigenated muriatic acid gas in a certain proportion, the elastic form of both fluids became destroyed, and an oil was produced; for which reason they called it *Olefiant gas*.

PROPERTIES OF HEAVY CARBONATED HIDROGEN GAS.

Heavy carbonated hidrogen gas is not absorbed or altered by water. Its weight compared with common air is as 909 to 1000. It has a disagreeable fetid odour, different from that of light carbonated hidrogen gas. It burns with a strong compact flame, similar to that of a resinous oil. When mixed with

oxigenated muriatic acid gas, its bulk is diminished, and an oil is formed. When the mixture of these two gases is fired, a quantity of charcoal is immediately deposited in the form of fine soot. Sulphuric, sulphureous, nitric, nitrous, and muriatic acids do not act upon it; neither does nitrous gas nor any of the fixed alcalies. Ammonia adds to its volume without occasioning any other change. Phosphorus heated in it even to fusion does not affect it. When made to pass through an ignited glass tube it does not diminish in volume, but loses the property of forming oil with oxigenated muriatic acid gas. Electric shocks passed through it, dilate, and likewise deprive it of this property. When passed through an ignited porcelain tube, it affords hidrogen gas, mingled with carbonic acid, and carbon is deposited. When passed through a tube with sulphur in fusion, sulphurated hidrogen gas is obtained, and charcoal deposited. When burnt with oxigen gas, or when passed through a red-hot tube filled with oxid of manganese, carbonic acid gas is formed.

METHODS OF OBTAINING HEAVY CARBONATED HIDROGEN GAS.

Heavy carbonated hidrogen gas is obtained by decomposing alcohol by sulphuric acid, at high temperatures. It is also obtained in abundance when alcohol or ether is passed through a red-hot earthen tube. Sulphuric ether mixed with sulphuric acid, and subjected to heat, also affords it, but in a less pure state.

The Dutch chemists observed, that if the vapour of ardent spirit or ether be made to pass through a glass tube, over the component parts of the earthen tube, namely, alumine and silex, this gas was also produced; or by passing it through a red-hot tube of pipe-clay.

In order to obtain this gas the following method may serve:

Let four parts of concentrated sulphuric acid and one of highly rectified ardent spirit be mingled together gradually in a glass retort, heat will be developed, the mixture will become brown,

and heavy carbonated hidrogen gas will be extricated without the application of external heat. When a moderate heat is applied, the action is very violent, and the gas is liberated very copiously, and may be received over water.

The gas obtained is always mixed with a considerable quantity of sulphureous acid gas, from which it may be freed by agitating it in contact with lime-water, or a solution of potash.

Remark....In this operation the heat ought to be regulated with great care, and the retort holding the mixture ought to be very capacious, otherwise the matter will be forced over into the receiver. The heat of a candle or lamp is sufficient.

Numerous experiments by different chemists have proved, that this species of carbonated hidrogen gas contains a larger quantity of carbon in solution than the former. This becomes obvious from the gas losing the property of forming oil by being made to pass through an ignited tube, for it then deposits charcoal, and becomes converted into light carbonated hidrogen gas.

The Dutch philosophers suppose that the disposition to form oil depends on the proximity of the constituent moleculæ of the gas; and the loss of this property they suppose to be owing to the separation of these moleculæ, by the introduction of a greater quantity of caloric.

Heavy carbonated hidrogen gas, they say, is converted into light carbonated hidrogen gas whenever a process is executed which increases the distance subsisting between its component parts. In this way the attraction between the particles of the hidrogen and carbon is diminished, which happens whenever the gas is made to pass through ignited tubes, capable of acquiring a high temperature, or by strongly electrifying it.

Either heavy or light carbonated hidrogen gas may therefore be obtained indiscriminately from the same substances, namely, ether or ardent spirit. Their difference arises from the different methods of treating these fluids, and is constantly reducible to this; that in forming the first gas, a less quantity of caloric, acts upon the mass, and a compound is formed in which the

hidrogen and charcoal are more concentrated, and more disposed to form oil by the addition of oxigen; whereas by more strongly heating the ardent spirit or ether, they become more completely decomposed; their constituent parts are removed to a greater distance, by a greater proportion of caloric being introduced between them, and the simultaneous attraction which might be disposed to form oil with oxigen, is so far diminished that they are no longer capable of that transition, therefore no oil can be formed.

Hence we perceive likewise why the specific gravity of the heavy carbonated hidrogen gas, when it loses its property of forming oil, becomes diminished.

We do not however agree with the Dutch chemists, that either the alumine, silex, or earthen tube serves to form this gas, as they assert, while glass tubes only afford the common carbonated hidrogen gas. These different effects certainly do not arise from the causes which are assigned to them. They seem to arise from a less degree of heat having been applied in all the cases where the heavy carbonated hidrogen gas was produced, and a greater degree in all those which present the light carbonated hidrogen gas.

Mr. Nicholson observed* that when ardent spirit is burnt in the lamp of Argand, and the lower aperture or air-passage of the lamp is kept open, the flame of the spirit is as usual faint and bluish, resembling that of carbonated hidrogen gas; but if the air-passage be obstructed by slowly applying the palm of the hand, or any more suitable obstacle the flame becomes more and more luminous, like that of oil, until in the progress of obstruction the aperture is so much closed that the combustion begins to decay for want of air. By a proper adjustment of the aperture, the spirit may be made to burn with a constant luminous white internal flame. In this case the temperature is precisely such as to produce the olefiant gas.

* Journal of Natural Philosophy, &c. May 1797, p. 55.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF HEAVY CARBONATED HIDROGEN GAS.

THE properties of this gas being similar to those of the other hidro-carbonates, it is unnecessary to exhibit experimental proofs of them; those already advanced under the head of light carbonated-hidrogen gas, will explain them all with the exception of its characteristic property of producing oil with oxigenated muriatic acid gas which shall be inserted here with a few other interesting remarks.

Experiment I.

Production of oil by the mixture of heavy carbonated hidrogen gas, with oxigenated muriatic acid gas.

Take a glass tube, send up into it three parts of *fresh prepared* heavy carbonated hidrogen gas, and add to it gradually four parts of *fresh prepared* oxigenated muriatic acid gas. After each addition of the gas, shake the mixture; an absorption will take place, caloric will be liberated, and the tube will become filled with white vapours. When the gases have totally disappeared an oil of a pearl grey colour will be deposited.

This oil is heavier than water, its odour is agreeable and penetrating, its taste is rather sweet. It becomes yellow by exposure to air.

Experiment II.

Conversion of heavy carbonated hidrogen gas, into light carbonated hidrogen by combustion with oxigen gas.

Let equal parts of fresh prepared heavy carbonated hidrogen gas, and oxigen gas be mingled together in a detonating tube, and a spark be passed through it, a momentary expansion will take place, the tube will become lined with a fine black soot of charcoal, and the heavy carbonated hidrogen gas will thus be converted into light carbonated hidrogen gas.

Mr. Cruikshank found that 100 cubic inches of carbonated hidrogen gas, obtained from alcohol, weighed 16 grains. It required 118 cubic inches of oxigen to saturate it, and produced 75 cubic inches of carbonic acid. This gas therefore consists of 7 carbon, 1.9 hidrogen and 7 water.

The same quantity of gas, obtained from ether, weighed 20 grains. It required for saturation 170 cubic inches of oxigen and produced 108 of carbonic acid. Hence this gas consisted of 9 carbon, 3 hidrogen, and 8 water.

One hundred cubic inches of carbonated hidrogen gas, obtained from camphor, weighed 21 grains. They consumed 176 cubic inches of oxigen, and produced 116 of carbonic acid; this gas consisted therefore of 11 carbon, 2 + hidrogen, and 8 or 9 water.

In the preceding estimate the weight of 100 cubic inches of common air, under the mean pressure of the atmosphere, and at the temperature of 55° is estimated at 31 grains. The quantity of carbon in carbonic acid at $\frac{1}{3}$ of the whole nearly, and the proportion of oxigen to hidrogen in water as about 85 to 15.

From the result of these experiments we perceive that the carbonated hidrogen gases obtained from various substances differ in their composition. This has given rise to the next species of gas.

GAZEOUS

OXID OF CARBON.

PART XXII.

GAZEOUS oxid of carbon was first described by Dr. Priestley, who mistook it for a hidro-carbonate.

With the true nature of it we have been only lately acquainted. It was first proved to be a peculiar gas, by Mr. Cruikshank of Woolwich, who made it known to us, as such, in April 1801, through the medium of Nicholson's Journal for that month. Several additional properties of this gas were soon afterwards noticed by Desormes, Clement and others. Gazeous oxid of carbon forms an intermediate substance between the pure hidro-carbonates and carbonic acid gas; but not being possessed of acid properties Mr. Cruikshank has called it, conformable to the rules of the chemical nomenclature, *gazeous oxid of carbon*, for it consists of oxigen and carbon rendered gazeous by caloric.

Though the gazeous oxid of carbon has some of the properties peculiar to the common hidro-carbonates, the following characteristic properties sufficiently prove that none of those at present known are similar to it. We are therefore entitled to consider it as a gas peculiar to itself.

SECT. I.

PROPERTIES

OF

GAZEOUS OXID OF CARBON.

GAZEOUS oxid of carbon is considerably lighter than any of the hidro-carbonates. It is lighter than common air in the proportion of 22 to 23. When mingled with common air and ignited it does not explode, but burns with a lambent blue flame, and the product is carbonic acid. It is very little absorbable by water; it is void of taste and odour. A mixture of 20 parts of gazeous oxid of carbon and 8 of oxigen gas, fired over mercury by electricity, diminishes to a volume equal to about 18 or 19 parts, which is carbonic acid gas. It contains neither water nor the basis of that fluid. It is exceedingly noxious, animals die in it instantly; when breathed for a few minutes only, it produces giddiness and fainting. Neither light, heat, nor electricity have any effect upon it. When equal quantities of gazeous oxid of carbon and hidrogen gas are passed through a red-hot glass tube, the tube is lined with charcoal, water is formed, and an excess of hidrogen makes its escape. If a piece of iron be put into the tube, it is oxidated, but not converted into steel. Neither nitrogen gas nor sulphur have any action on it even at high temperatures. It is capable of dissolving a minute quantity of charcoal and increases in bulk. It dissolves phosphorus and acquires the property of burning with a yellow flame. The alcalies have no effect on this gas. It is not altered when passed with

ammonia through an ignited tube. When the red oxid of mercury is heated in it, a commencement of reduction takes place. Neither sulphuric, nitric, nor nitro-muriatic acids, alter it when passed with it through a red-hot tube. Four parts of oxigenated muriatic acid gas left with one of carbonic acid gas, decompose it completely. Nitrous gas has no effect upon it. When mixed with sulphurated hidrogen gas, and passed through a red-hot tube, sulphur is deposited, and sulphurated hidrogen gas remains mixed with gazeous oxid of carbon.

METHODS OF OBTAINING GAZEOUS OXID OF CARBON.

Gazeous oxid of carbon may be obtained by a decomposition of carbonic acid at high temperatures, by means of various fixed substances which have a considerable affinity to oxigen. This may be done by distilling a mixture of charcoal with any of the metallic oxids, or by exposing to a strong red heat, a mixture of carbonate of lime or barytes, and filings of iron, zinc, &c.

The method of obtaining the gazeous oxid of carbon in a state of purity, recommended by Mr. Cruikshank, is the following:

1. Take one part of chalk previously exposed to a low red heat for about ten minutes, mix it with an equal quantity of perfectly dry filings of zinc; let the mixture be introduced into a retort, and expose it to a heat gradually increased. As soon as the retort becomes of a dull red heat, gas will be disengaged in great abundance. The gas which comes over first is carbonic acid gas, but as soon as the retort becomes thoroughly ignited, pure gazeous oxid of carbon is liberated in a prodigious quantity, which may be collected in the usual manner over water.

Rationale...In this process a decomposition of the carbonic acid of the chalk takes place in its nascent state. The zinc robs the carbonic acid of part of its oxigen at a high temperature, and becomes to a certain degree oxidated. The carbonic acid by

being thus deprived of part of its oxigen, becomes converted into a new inflammable gas called gazeous oxid of carbon.

Remark...Upon the whole therefore we have to consider this gas as holding the same relation to pure hidro-carbonates and carbonic acid gas, which nitrous gas or nitrous oxid does to pure nitrogen and nitrous acid.

Tin, and probably various other metals, when mingled with charcoal, are capable of producing gazeous oxid of carbon in a similar manner.

2. Gazeous oxid of carbon may also be obtained in the following manner:

Take equal quantities of scales of iron separated in forging, (grey oxid of iron) and charcoal powder previously heated to redness; mix them together, introduce the mixture into a coated glass retort, or gun-barrel, and apply heat gradually; as soon as the retort becomes of a dull red heat, gas is produced in great abundance. It consists of about one part of carbonic acid gas and four of gazeous oxid of carbon. In order to separate the carbonic acid gas, it must be suffered to stand over slaked lime or agitated with lime-water; the carbonic acid gas will be absorbed, and what remains behind is pure inflammable gazeous oxid of carbon; or this trouble may be saved by letting the gas as it is disengaged pass through lime, formed into a very thin paste with water. The carbonic acid combines with the lime; but the gazeous oxid of carbon passes through it unaltered.

Rationale...The production of gazeous oxid of carbon in this manner is in some respects analogous to the former. The grey oxid of iron parts with a portion of its oxigen which joins to the carbon to form the gazeous oxid, and another part is liberated in the form of carbonic acid gas. The grey oxid of iron therefore re-approaches to the metallic state.

A mixture of charcoal and oxid of zinc, red oxid of copper, semi-vitreous oxid of lead, black oxid of manganese, and the rest of the metallic oxids capable of enduring a red heat, on being treated with charcoal also yields carbonic acid gas and ga-

zeous oxid of carbon. Those oxids which retain their oxigen most obstinately yield most of the latter, and those which part with it readily afford most carbonic acid gas. The latter comes over chiefly at the beginning and the former towards the end of the process.

Inferences...From these various facts there can no longer remain any doubt but that the carbonic acid, under certain elevations of temperature, may be decomposed by any fixed substance having a considerable affinity with oxigen, and that with regard to the metals, those succeed the best which have the greatest attraction for acids or oxigen, as is the case with zinc. Upon the whole we may conclude that there are but two distinct combinations of carbon and oxigen capable of assuming and maintaining the form of gas. For although the gazeous oxid of carbon may be obtained in a great variety of ways, by direct composition, as well as during the decomposition of the carbonic acid, yet when pure, it is exactly the same substance, having the same specific gravity, requiring the same portion of oxigen to saturate it, and producing the same quantity of carbonic acid, as Mr. Cruikshank* has sufficiently proved experimentally to what the different results of impure gases are owing.

One hundred cubic inches of gazeous oxid of carbon, obtained from iron filings and carbonate of lime or barytes, previously ignited, according to Mr. Cruikshank weigh 30 grains. They require 40 cubic inches (13.6 grains) of oxigen for saturation, and form 92 cubic inches (43.2 grains) of carbonic acid, and no water is produced. Hence the 100 cubic inches of gazeous oxid of carbon consist of 21 + oxigen 8.6 carbon.

One hundred cubic inches of the same gas obtained from charcoal and metallic oxids, weigh 30 grains. They require 44 cubic inches (15 grains) of oxigen for saturation, and yield 76 cubic inches (35.5 grains) of carbonic acid, and afford (on account of the hidrogen contained in the charcoal) about 8 grains of water.

* Nicholson's Journal, Sep. 1801, p. 210.

Hence this gas consists of about 15 oxigen, 7 carbon, 1 + hidrogen, and an uncertain quantity of water.

REMARK...The quantity of oxigen in the gazeous oxids, Mr. Cruikshank estimated thus:...In the first instance, for example, we find that 30 grains of the oxid combined with 13.6 grains of oxigen, produced 43.3 grains of carbonic acid. This acid consists of 8.6 grains of carbon and 34.6 of oxigen nearly; but the quantity of oxigen employed in the experiment was only 13.6 grains; hence the difference between 34.6 and 13.6 or 21 grains, must have been originally contained in the oxid. It would therefore appear that the gazeous oxids in their purest state consist of oxigen and carbon, in the proportion of 21 to 9 nearly, combined with caloric.

Upon the whole, we consider as mentioned before, the gazeous oxid of carbon as holding the same relation to the pure hidrocarbonates and carbonic acid, which nitrous gas, or nitrous oxid does to pure nitrogen and nitrous acid.

SULPHURATED HIDROGEN GAS.

PART XXIII.

SECT. I.

PROPERTIES OF SULPHURATED HIDROGEN GAS.

SULPHURATED hidrogen gas possesses the properties of an acid; for when absorbed by water its solution reddens vegetable blues; it combines also with alcalies, earths, and with several metallic oxids. Sulphurated hidrogen gas possesses an extremely offensive odour, resembling that of putrid eggs. It kills animals, and extinguishes burning bodies. When mixed with oxigen gas, or atmospheric air, it is inflammable. Mingled with nitrous gas it burns with a yellowish green flame. It is decomposed by ammonia, by oxigenated muriatic acid gas, and by sulphureous acid gas. It has a strong action on the greater number of metallic oxids. Its specific gravity to common air is as 1106

to 1000. It is composed, according to Thenart, of 70.857 sulphur and 29.143 hidrogen. It has the property of dissolving a small quantity of phosphorus.

METHODS OF OBTAINING SULPHURATED HIDROGEN GAS.

1. Take dry sulphuret of potash, put it into a tubulated retort lodged in a sand bath, or supported over a lamp, direct the neck of the retort under a receiver placed in the pneumatic trough; then pour gradually upon the sulphuret diluted sulphuric, or muriatic acid; a violent effervescence will take place, and sulphurated hidrogen gas will be liberated. When no more gas is produced spontaneously, urge the mixture with heat by degrees till it boils, and gas will again be liberated abundantly.

The water made use of for receiving it should be heated to about 80° or 90°; at this temperature it dissolves little of the gas, whereas if cold water be made use of, a vast quantity of it is absorbed.

RATIONALE...Though sulphur makes no alteration on water, which proves that sulphur has less attraction for oxigen, than hidrogen has, yet if sulphur be united to an alcali, this combination decomposes water whenever it comes into contact with it, though the alcali itself has no attraction either for oxigen or hidrogen.

The formation of this gas explains this truth. On adding the sulphuret of potash to the water, this fluid becomes decomposed, part of the sulphur robs it of its oxigen, and forms with it sulphuric acid, this generated acid unites to part of the alcali and forms sulphate of potash. The liberated hidrogen dissolves another part of the sulphur, and forms with it sulphurated hidrogen; the basis of this gas, which is retained by the separated portion of the alcali. The sulphuric acid added now extricates it from the alcali, and makes it fly off in the form of gas.

The mixture in the retort therefore contains an alcaline sulphure properly so called, or the simple combination of sulphur with alcali; sulphate of potash, and lastly, sulphurated hidrogen gas dissolved in the alcaline sulphure, or an hidrogenated sulphuret.

Remark...Diluted muriatic acid is best adapted for the production of sulphurated hidrogen gas from alcaline sulphurets. If nitric acid be made use of it must be much diluted. Sulphuric acid yields little gas, unless assisted by heat. When the proportion of sulphur in the sulphuret exceeds that of the alcali, the dense sulphuric acid poured upon it emits sulphuric acid gas much loaded with sulphur. All the rest of the acids may be made use of for decomposing the sulphurets.

2. When iron and sulphur are united together, they afford a large quantity of sulphurated hidrogen gas on submitting them to the action of heat, in contact with water.

Melt together in a crucible equal parts of iron filings and sulphur; the product is a black brittle mass called sulphuret of iron. Reduce this to powder, and put it with a little water into a tubulated retort; add diluted muriatic acid, and apply a gentle heat, till no more gas is disengaged.

Rationale...The philosophy of this experiment is analogous to the former. Part of the oxigen of the water unites to part of the sulphur, and forms sulphuric acid, another part oxidates the iron, which dissolved by the acid forms sulphate of iron: the hidrogen of the water unites to another part of the sulphur, and forms sulphurated hidrogen, which becomes gazeous by the addition of caloric.

3. Sulphurated hidrogen gas may also be obtained by heating an alcaline sulphuret, with the addition of water, without the affusion of an acid.

Rationale...In this case the water is also decomposed; its hidrogen unites with part of the sulphur, and forms sulphurated hidrogen, the oxigen of the water unites with another part of the sulphur and produces sulphuric acid, which joins to the alcali

and forms a sulphate. The sulphurated hidrogen becomes disengaged by heat in the gazeous form.

4. Sulphurated hidrogen gas may be obtained by passing hidrogen gas through sulphur in a state of fusion.

For this purpose put sulphur into a gun-barrel, or Wedgwood's tube, and place it across a furnace; fit to the lower extremity a bent glass tube, which goes under a receiver placed in the pneumatic trough, and adapt to the upper extremity a tubulated retort or other apparatus proper for producing hidrogen gas. The sulphur must then be heated and when melted, and the hidrogen gas evolved, must be made to pass over it, which in this manner will dissolve part of the sulphur, and become converted into sulphurated hidrogen gas.

5. It may likewise be procured in a direct manner; for that purpose let a small quantity of sulphur be inclosed in a jar full of hidrogen gas, and melt it by means of a burning glass.

REMARK...This method does not succeed except the hidrogen gas be as dry as possible, for its affinity to sulphur is weakened in proportion to its moisture.

SECT. II.

EXPERIMENTAL PROOFS

OF THE

PROPERTIES OF SULPHURATED HIDROGEN GAS.

Experiment I.

Sulphurated hidrogen gas is absorbed by water.

FILL a bottle with sulphurated hidrogen gas, and keep it inverted in a bason of cold water; an absorption will take place which may be accelerated by agitation. The water which has absorbed a quantity, has the fetid odour of the gas. It is not decomposed by exposure to the air; but the gas is gradually separated and carried off without decomposition. Water impregnated with sulphurated hidrogen gas slightly reddens blue vegetable colours.

Remark...It is this gas which gives to the mineral waters of Harrogate and Aix-la-Chapelle their peculiar smell. Such waters may therefore be artificially imitated by impregnating pure water with this gas, and adding the other constitutent parts to it.

Experiment II.

Sulphurated hidrogen gas is inflammable in contact with oxigen gas.

Mix equal parts of sulphurated hidrogen gas and oxigen gas over water, and apply a lighted taper; a smart detonation will take place, and both gases will disappear.

RATIONALE...Part of the oxigen unites to the hidrogen of the sulphurated hidrogen gas; another part joins to the sulphur suspended in this gas, hence the products after combustion are sulphureous acid and water.

EXPERIMENT III.

Sulphurated hidrogen gas mingled with nitrous gas burns with a yellowish-green flame.

If three parts of sulphurated hidrogen gas be mixt with two of nitrous gas the mixture may be inflamed, and burns with a yellowish-green flame; the vessel becomes lined with a coat of sulphur.

RATIONALE...The explanation of these phenomena are analogous to the rationale of the next experiment.

EXPERIMENT IV.

Sulphurated hidrogen gas is decomposed by atmospheric air.

Introduce into a bell-glass, half filled with sulphurated hidrogen gas, an equal quantity of atmospheric air, a diminution will take place, sulphur will be precipitated, and nitrogen be left behind.

RATIONALE...The oxigen of the atmospheric air has a greater affinity for hidrogen than the sulphur of the sulphurated hidrogen gas has; they therefore unite and form water, and the sulphur becomes deposited.

REMARK...On this principle it is, that water holding sulphurated hidrogen gas in solution lets fall sulphur on exposure to the open air; and hence arises the sulphur seen deposited in the channels, and in the neighbourhood of sulphurated or as they are commonly called, hepatic waters.

Experiment V.

Sulphurated hidrogen gas becomes quickly absorbed by alcaline solutions.

This may be proved by filling a tube with the gas, and inverting it in a bason containing some concentrated solution of potash. The gas will be absorbed and the potash will acquire colour, odour, and other peculiar properties.

This combination is called *hidro-sulphuret of potash*; it is a true saline compound.

Remark...Hitherto only the alcalies and some of the earths have been combined with sulphurated hidrogen gas. These compounds are colourless while kept in close vessels, but when exposed to air, they soon acquire colour. This change is produced by the decomposition of part of the sulphurated hidrogen gas by the air. The hidrogen combines with the oxigen of the air, and forms water, while the sulphur is disengaged, and thus darkens the colour.

The sulphurated hidrogen gas may again be expelled from these combinations in the same ratio it had been absorbed, by the addition of an acid. It may also be disengaged by heat.

Experiment VI.

Sulphurated hidrogen gas and sulphureous acid gas decompose each other.

When sulphurated hidrogen gas and sulphureous acid gas are mingled together over mercury, the volume of the gases becomes diminished, and sulphur is deposited on the sides of the vessel in a considerable quantity.

When these gases are dissolved in water, they mutually undergo the same decomposition. If suitable quantities are taken, the odour of both fluids disappears instantly.

RATIONALE...The hidrogen of the sulphurated hidrogen gas has a greater affinity for the oxigen of the sulphureous acid gas, than the sulphur has; they therefore unite and form water, and the sulphur of both is deposited.

REMARK...If concentrated nitrous acid be poured copiously into water holding sulphurated hidrogen gas in solution, sulphur is likewise deposited. Hence nitrous acid is used as a test to detect the presence of sulphurated hidrogen gas in hepatised waters.

EXPERIMENT VII.

Combination of sulphurated hidrogen gas and ammonia.

Fill a glass jar with fresh prepared sulphurated hidrogen gas, confined over mercury, and add to it gradually ammoniacal gas; a dense white vapour will instantly appear; both gases will vanish, and a white saline compound will be formed, being hidrogenated sulphuret of ammonia.

EXPERIMENT VIII.

Oxigenated muriatic acid gas, and sulphurated hidrogen gas likewise decompose each other.

Fill a cylindrical vessel over water with oxigenated muriatic acid gas, keep it over that fluid and mingle it with sulphurated hidrogen gas; at the instant the gases come in contact with each other, their bulk will be diminished, and the vessel become lined with sulphur.

RATIONALE...The oxigen of the oxigenated muriatic acid gas unites partly to the sulphurated hidrogen, and partly to the sulphur dissolved in that gas; hence water and sulphuric acid are formed; the oxigenated muriatic acid gas being robbed of its oxigen becomes converted into simple muriatic acid, and the sulphur which escaped the action of the oxigen is precipitated.

Experiment IX.

Decomposition of sulphurated hidrogen gas by the electric spark.

Fill a detonating tube over water with sulphurated hidrogen gas, and pass the electric spark through it, the volume of the gas will become diminished and sulphur be precipitated.

Experiment X.

Sulphurated hidrogen gas acts strongly on the greater number of metallic oxids.

Dip a slip of paper into a solution of silver, lead, bismuth, mercury, tin, &c. and expose it to the action of sulphurated hidrogen gas, the paper will instantly become blackened. Writings performed with these solutions are invisible when dry, but become visible when immersed in a bottle filled with this gas.

Rationale...In this instance the hidrogen of the gas abstracts the oxigen from these bodies, and causes them to re-approach to the metallic state; at the same time, the sulphur contained in the gas combines with the metal thus regenerated and converts it into a sulphuret.

PHOSPHORATED HIDROGEN GAS.

PART XXIV.

SECT. I.

WE are indebted to M. Gengembre for the discovery of this gas, which differs from the hidro-carbonates in nothing but the nature of the combustible substance suspended in the hidrogen gas.

Phosphorated hidrogen gas consists of phosphorus dissolved in hidrogen gas.

PROPERTIES OF PHOSPHORATED HIDROGEN GAS.

Phosphorated hidrogen gas is the most combustible substance in nature. It is particularly distinguished from all other gases, by the property of taking fire immediately when brought in contact with atmospheric air. When mixed with oxigen gas, or with oxigenated muriatic acid gas, it burns with great vehemence. When bubbles of it are suffered to pass through

water, they explode in succession as they reach the surface of this fluid. It has an insupportable odour similar to that of putrid fish. It is partly absorbable by distilled water freed from atmospheric air at low temperatures. Distilled water absorbs about one-fourth, and gives it out again without alteration by heat. Water containing atmospheric air decomposes it, when suffered to stand with it for some time. When exposed to vivid light, it deposits phosphorus in a crystalline form.

METHODS OF OBTAINING PHOSPHORATED HIDROGEN GAS.

1. Take a small retort, put into it one part of phosphorus and ten of a concentrated solution of potash or soda; make the mixture boil and receive the liberated gas over mercury; or if it be intended for immediate use, it may be collected over water.

RATIONALE...In this experiment a decomposition of the water takes place. Its oxigen unites to part of the phosphorus and forms phosphoric acid, which joins to the potash and forms phosphate of potash. The liberated hidrogen dissolves another part of the phosphorus and becomes converted into phosphorated hidrogen gas.

REMARK...In thus preparing this gas, the body of the retort should be filled as nearly as possible with the mixture, otherwise the first portion of gas which is produced inflames in the retort; a vacuum is formed, and the water forced up into the retort, and endangers the bursting of it.

2. Phosphorated hidrogen gas is also obtained, if by a direct exposure to a strong heat we effect a combination of phosphorus and lime (see p. 165) and then throw this compound into water, a great quantity of phosphorated hidrogen gas will soon be formed, and may be collected in the usual manner over water or mercury.

RATIONALE...The production of phosphorated hidrogen gas in this manner is analogous to the first, with the only difference

that here the decomposition of the water takes place at common temperatures.

3. Phosphorated hidrogen gas may also be obtained, according to Davy,* in the following manner:

Let water be decomposed in the usual manner, by means of zinc and sulphuric acid, and add to the mixture a quantity of phosphorus. The hidrogen evolved will dissolve part of the phosphorus; phosphorated hidrogen gas will be produced, and take fire at the surface of the fluid, so long as the decomposition of the water is made, with considerable rapidity. But the gas produced in this process burns with a more lambent flame than that obtained in the usual manner, probably on account of containing a larger quantity of hidrogen. The experiment is nevertheless brilliant; for the gas is disengaged in small bubbles, which cover the whole surface of the fluid; they disengage themselves rapidly, new ones are produced, and the whole fluid resembles a well of fire.

Remark...For the success of this experiment, it is essential that the water, during the action of its decomposition, be considerably heated, which may be effected by a copious addition of sulphuric acid, and that the phosphorus be present in a considerable quantity. Half a part of phosphorus cut into small pieces, one of granulated zinc, three of concentrated sulphuric acid, and five of water, answer this purpose exceedingly well.

Phosphorated hidrogen gas is also produced by nature. The air which burns at the surface of certain springs, and forms what is called *burning springs* and the *ignis fatui* (Jack o'lanterns) which glide along burying-grounds, or places where animal matters are putrifying, consist of hidrogen gas, holding phosphorus in solution.

* Nicholson's Journal, April 1802.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF PHOSPHORATED HIDROGEN GAS.

EXPERIMENT I.

Phosphorated hidrogen gas takes fire on coming into contact with atmospheric air.

THIS may be evinced by charging a small retort with potash, phosphorus, and water, in the manner mentioned before, applying heat and dipping the mouth of the retort into a bason of water. The bubbles of air which come from the retort and pass through the water will burst with a slight explosion and produce flashes of fire in the circumambient air. A circular dense white smoke rises horizontally like a ring, enlarging itself continually, and forming a sort of *corona* extremely beautiful if the air be perfectly tranquil.

The finest effect is produced when the flashes of gas succeed each other but slowly.

RATIONALE...We have noticed before, that phosphorated hidrogen gas, is nothing but hidrogen gas holding phosphorus in solution. When this gazeous fluid is presented to the atmos-

pheric air or oxigen gas, the minutely divided phosphorus rapidly attracts oxigen and kindles, setting fire at the same time to the hidrogen gas in contact with atmospheric air, and hence phosphoric acid and water are formed.

The circular crown of white smoke which rises after the explosion of the gas, originates from the coat of water which enveloped the bubble of the gas; this water, together with what is formed during the explosion, is suddenly converted into vapour, it unites to the phosphoric acid produced and thus constitutes the circular crown of smoke which rises like a ring.

If a wide-mouthed phial be filled with phosphorated hidrogen gas and left in that situation over mercury, the gas will take fire when suffered to escape into the air by inclining the phial.

Remark....This last is a hazardous experiment, the phial is often burst to pieces; it is therefore necessary to surround it with a cloth in order to avoid dangerous events. An elastic gum bottle may be used for this purpose with safety.

Experiment II.

Accension of phosphorated hidrogen gas by means of oxigen gas.

Fill a receiver with oxigen gas and convey into it a few bubbles of phosphorated hidrogen gas. At the instant of the union of the gases, a brilliant flash of fire takes place, accompanied with a report.

The rationale of this experiment is analogous to the former.

Remark...Great caution is necessary in performing this experiment. The dilatation of the gases which takes place during the explosion is so great that the vessel is apt to be blown to pieces. Not more than a single small bubble of the phosphorated hidrogen gas should be conveyed into the oxigen gas at once, except the receiver be made of very thick glass.

Experiment III.

Accension of phosphorated hidrogen gas, by means of oxigenated muriatic acid gas.

If fresh-prepared phosphorated hidrogen gas and oxigenated muriatic acid gas are mingled together over mercury, a considerable detonation takes place, accompanied with a lambent green flame, and dense white vapours.

Rationale...All that happened in the last experiments takes place in this instance. The oxigenated muriatic acid gas is robbed of its oxigen, and becomes converted into simple muriatic acid gas; and water and phosphoric acid are produced. The evolved heat inflames the phosphorus which was dissolved in the gas.

Remark...For the success of this experiment it is essential that both gases are fresh prepared. The receiver in which the mixture is made should be very strong, in order to guard against accidents.

Experiment IV.

Phosphorated hidrogen gas burns with a green light in nascent oxigenated muriatic acid gas, under the surface of water.

Put into an ale-glass, or Florence flask, one part of phosphoret of lime, broken into pieces of the size of a pea (*not in small fragments or in powder,*) and add to it half a part of oxigenated muriate of potash. Fill the vessel with water, and bring carefully into contact with the materials at the bottom of the fluid, three or four parts of concentrated sulphuric acid. This may be most conveniently done, by letting the acid fall through a long-necked funnel, reaching to the bottom of the vessel, or by causing it to pass down the sides of it. As soon as the decom-

position of the water, and that of the oxigenated muriate, takes place, flashes of fire dart from the surface of the fluid, and the phosphoret illuminates the bottom of the vessel with a beautiful green light.

Experiment V.

A ribbon or piece of silk, impregnated with a solution of gold, may be gilt by the action of phosphorated hidrogen gas.

Take a silk ribbon, wet it thoroughly with a solution of pure muriate of gold, and expose it over mercury to the action of phosphorated hidrogen gas for a few days; the ribbon in this situation will become covered with gold. The gilding is so permanent that it will bear washing.

Rationale...The hidrogen of the phosphorated hidrogen gas unites to part of the oxid of gold dissolved in the acid and forms water. The phosphorus thus separated unites to another part of the oxigen and produces phosphoric acid. The gold therefore on losing its oxigen totally, becomes reduced to the metallic state and attaches itself by virtue of a strong molecular attraction to the ribbon.

Remark...One part of crystallized muriate of gold, dissolved in eighteen parts of distilled water seems to answer this purpose extremely well.

If the gilding be repeated a second, or even a third time, its lustre becomes extremely beautiful.

Experiment VI.

Phosphorated hidrogen gas and sulphureous acid gas decompose each other.

Let phosphorated hidrogen gas and sulphureous acid gas, both obtained over mercury, be mingled together, the two gases will

lose their elasticity; plates of yellow matter are deposited on the sides of the vessel, which take fire on hot iron, first in the manner of phosphorus, and afterwards with the characters of sulphur.

RATIONALE...It follows from this experiment that the hidrogen is the only substance which combines with the oxigen in these circumstances, since the gases lose their fluidity and deposit respectively the sulphur and phosphorus contained in them.

EXPERIMENT VII.

Phosphorated hidrogen gas is decomposed by vivid light.

Though phosphorated hidrogen gas may be kept over mercury in the dark, for any length of time unaltered, this is not the case if the gas be exposed to light. If a bottle filled with this gas, be painted partly black, or surrounded with black paper, and then exposed to the light of the sun, the union of the phosphorus and hidrogen will be broken, and the phosphorus will be found crystallized at those parts through which the rays of light were suffered to pass, and the hidrogen gas will be left behind.

NITROUS GAS.

PART XXV.

SECT. I.

THE name of nitrous gas is given to an aeriform fluid, consisting of a certain quantity of nitrogen gas and oxigen; first described by Priestley, but in some measure known before to Hales.

PROPERTIES OF NITROUS GAS.

Nitrous gas is an elastic, colourless fluid, having no sensible taste; it is neither acid nor alcaline; it is exceedingly hurtful to animals, producing instant suffocation whenever they attempt to breathe it. The greater number of combustible bodies refuse to burn in it. It is nevertheless capable of supporting the combustion of some of these bodies. Phosphorus burns in nitrous gas when introduced into it in a state of inflammation; pyrophorus takes fire in it spontaneously.

It is not decomposable by water, though 100 cubic inches of this fluid when freed from air, absorb about 11.8 cubic inches of gas. This solution is void of taste; it does not redden blue vegetable colours; the gas is expelled again when the water is made to boil or suffered to freeze. It has no action on nitrogen gas even when assisted by heat. It is decomposed by several metals at high temperatures.

Its specific gravity, when perfectly pure, is to that of atmospheric air as 1.093 to 1.

Ardent spirit, saccharine matters, hidro-carbonates, sulphureous acid and phosphorus have no action on it. It is not sensibly changed by the action of light. Heat dilates it. It rapidly combines with oxigen gas at common temperatures, and converts it into nitrous acid. Atmospheric air produces the same effect but with less intensity. It is absorbable by green sulphate, muriate and nitrate of iron, and decomposable by alcaline, terrene, and metallic sulphurets, and other bodies that have a strong affinity for oxigen; but it is not capable of combining with them chemically, so as to form saline compounds. From the greatest number of bodies which absorb it, it may be again expelled by the application of heat.

It communicates to flame a greenish colour before extinguishing it; when mixed with hidrogen gas it acquires the property of burning with a green flame. It is absorbable by nitric acid and renders it fuming.

When exposed to the action of caloric in an ignited porcelain tube, it experiences no alteration, but when electric sparks are made to pass through it, it is decomposed and converted into nitrous acid, and nitrogen gas. Phosphorus does not shine in it. It is composed of 56 parts of oxigen and 44 nitrogen.

METHODS OF OBTAINING NITROUS GAS.

1. Put into a small proof or retort, some copper wire or pieces of the same metal, and pour on it nitric acid of commerce di-

luted with water, an effervescence takes place and nitrous gas will be produced. After having suffered the gas to escape for a few minutes on account of the atmospheric air contained in the retort, collect the gas in the water-apparatus as usual. In order to obtain the gas in a pure state, it must then be shook for some time in contact with water.

RATIONALE...We have seen before (page 197) that water was decomposed on bringing in contact with it a metal and an acid; but here the case is different; the water in this instance suffers no alteration, on the contrary, the acid undergoes a partial decomposition; the metal robs the nitric acid of the greatest part of its oxigen and becomes oxidated; the remainder of the acid having lost so much of its oxigen, becomes thereby so altered, that at the usual temperature it can exist no longer in the liquid state, but instantly expands and assumes the form of gas; ceasing at the same time to act as an acid and exhibiting different properties.

Instead of presenting copper to nitric acid, iron, zinc, mercury, or silver may be made use of. The metals best suited for the production of nitrous gas are silver, mercury, and copper.

2. Nitrous gas may likewise be obtained by synthesis. This method of obtaining it we owe to Dr. Milner of Cambridge.

Into the middle of an earthen tube about 20 inches long and $\frac{3}{4}$ wide, open at both ends, put as much coarsely powdered manganese as is sufficient nearly to fill it. Let this tube traverse a furnace having two openings opposite to each other. To one end of the tube lute a retort containing water strongly impregnated with ammonia, and to the other adapt a bent glass tube which passes into the pneumatic trough. Let a fire be kindled in the furnace, and when the manganese may be supposed to be red-hot, apply a gentle heat to the retort and drive over it the vapour of the ammonia; the consequence will be that nitrous gas will be delivered at one end of the tube, at the time that the ammonia enters the other end; and this effect does not take place without the presence of the alcali.

RATIONALE...Ammonia consists of hidrogen and nitrogen, its hidrogen combines with the oxigen which is given out by the ignited manganese, and forms water, its nitrogen unites at the same time to another portion of the oxigen and constitutes the nitrous gas.

REMARK...There is a cause of deception in this experiment, against which the operator ought to be on his guard, lest he should conclude no nitrous gas is formed, when in reality there is a considerable quantity. The ammonia, notwithstanding every precaution will frequently pass over undecomposed. If the receiver in the pneumatic trough is filled with water, great part of this will indeed be presently absorbed; but still some portion of it will mix with the nitrous gas formed in the process. Upon admitting the atmospheric air, the nitrous gas will become decomposed, and the red nitrous fumes instantly unite with the alcali. The receiver is presently filled with white clouds of nitrate of ammonia; and in this manner a wrong conclusion may easily be drawn from the want of the orange colour of the nitrous fumes. A considerable quantity of nitrous gas may have been formed, and yet no orange colour appear, owing to this circumstance; and therefore it is easy to understand how a small quantity of nitrous gas may be most effectually disguised by the same cause.

Dr. Milner* also obtained nitrous gas, by passing ammoniacal gas over sulphate of iron deprived of its water of crystallization.

* Phil. Trans. LXXIX, p. 300.

SECT. II.

EXPERIMENTAL PROOFS

OF

THE PROPERTIES OF NITROUS GAS.

Experiment I.

Nitrous gas decomposes atmospheric air.

It was mentioned before that nitrous gas greedily attracts oxigen gas and atmospheric air. We shall demonstrate this fact and show at the same time that during this union, an acid is produced.

Pass up into a cylindrical glass vessel, over water, about one measure of nitrous gas and two of common air; the two fluids will speedily unite, red fumes will be produced, and the volume of the two combined gases will be diminished. A considerable degree of heat will be perceived, the water will rise in the cylinder and absorb the red vapours. When the two gases have been mixed in due proportion, nothing remains at last but the nitrogen gas of the atmospheric air. Usually 16 measures of common air are requisite to destroy completely $7\frac{1}{3}$ measures of nitrous gas; this however varies according to the purity of the airs.

Rationale...The nitrous gas in this experiment decomposes the atmospheric air; it takes the oxigen from the nitrogen gas,

unites with it and forms nitrous acid; the nitrogen is therefore left behind; the heat which is generated is the caloric which kept the gases in solution which now becomes liberated.

If instead of atmospheric air, oxigen gas be substituted, this phenomenon will be still more striking. If a pint of pure oxigen gas be mixed with two of nitrous gas the redness will be much greater, and the volume of the gases almost entirely disappear.

Remark...Upon the property which nitrous gas has of absorbing the oxigen of the atmosphere, Priestley and Fontana founded the construction of their eudiometers already mentioned.

Experiment II.

Proofs that an acid is produced during the mixture of nitrous gas and atmospheric air or oxigen gas.

Paste a slip of litmus paper within a glass jar, near the bottom, and into the jar, filled with and inverted in water, pass as much nitrous gas, previously well washed, as will displace the fluid below the level of the paper; the blue colour of the paper will remain unaltered, but on sending up atmospheric air or oxigen gas, it will immediately change its blue colour to red. A sure proof that an acid has been formed.

That it is nitrous acid which is produced by the union of nitrous gas and oxigen gas, may be evinced in the following

Experiment III.

Into a jar filled with and inverted over mercury, put a small quantity of solution of pure potash, and afterwards measures of oxigen and nitrous gases separately, and in proper proportion, as long as an absorption takes place. On removing the solution from the jar and evaporating it in a glass bason, crystals of salt will be formed which exhibit all the properties of nitrate of potash.

Experiment IV.

Nitrous gas is absorbed by nitric acid, to which it gives new characters.

Let nitrous gas pass as it is liberated from the materials which afford it, into a bottle containing colourless nitric acid, the acid will first become yellow, then green, next orange-coloured, and at last dark olive-coloured and fuming.

Rationale...The change of colour depends on the absorption of different quantities of nitrous gas. Priestley found that 100 parts of nitric acid of a moderate strength, absorbed in two days 90.29 of [illegible] gas. He informs us that when about seven parts were absorbed, the acid assumed an orange colour; when eighteen parts were absorbed, a green colour; and that when the 90.29 were combined, it became red and fuming.

Remark...If the olive-coloured acid be diluted with water, it becomes blue; the orange-coloured when united with water becomes emerald-green; and a large quantity of water renders either of them colourless.

Experiment V.

Nitrous gas which has been absorbed by nitric acid may be expelled again from this fluid.

This may be shown by gently heating the acid coloured in the before-going experiment till it becomes limpid. In this experiment light should be excluded.

Rationale...The nitrous gas absorbed by the acid has a greater affinity for caloric than the nitric acid has; this property therefore is here employed for disengaging the nitrous gas which rendered the acid fuming.

Experiment VI.

Nitrous gas tinges the flame of burning bodies green.

Fill a wide-mouthed bottle with a mixture of one part of nitrous gas, and four of hidrogen gas; set fire to it with a lighted taper, and the mixture will burn with a green flame.

If a lighted taper be immersed in nitrous gas, it exhibits a green flame before the taper becomes extinguished.

Experiment VII.

Nitrous gas is unfit for maintaining the combustion of the greater number of burning bodies.

Fill a receiver with nitrous gas, and let down into it a burning taper; the taper will instantly be extinguished; the same thing will happen to ardent spirit, oils, &c. though burning with a vivid flame.

That nitrous gas however is capable of supporting the combustion of other bodies will be obvious from the following experiments:

Experiment VIII.

Accension of pyrophorus in nitrous gas.

Place some new-made pyrophorus in a copper spoon, and introduce it into a receiver filled with nitrous gas; the pyrophorus will instantly take fire and the volume of the gas will become diminished.

Rationale...The pyrophorus effects a real analysis of the gas, it subtracts its oxigen and leaves its nitrogen behind; hence if the remaining air be examined it will be found that it renders

lime, or barytic water turbid, and that it undergoes no further diminution when mingled with oxigen gas; it is therefore a mixture of carbonic acid and nitrogen gas.

Experiment IX.

Nitrous gas maintains the combustion of phosphorus when introduced in a state of actual inflammation.

Though phosphorus may be fused and even sublimed in nitrous gas without producing the slightest luminous appearance, if the gas be perfectly pure; yet if a bit of phosphorus be placed in a copper ladle, then inflamed and introduced into the gas when in a state of actual inflammation, it burns with almost as much brilliancy as in oxigen gas.

Rationale...The rationale of this experiment proves that at the heat of ignition, phosphorus is capable of disturbing the equilibrium of the affinity subsisting between oxigen and nitrogen in nitrous gas, on which account it attracts the former from the nitrous gas and leaves the latter behind.

Experiment X.

Nitrous gas inflames charcoal when introduced in a state of ignition.

If a piece of ignited charcoal be introduced into nitrous gas there will also be a vivid inflammation; this experiment may likewise be performed by setting fire to the charcoal confined in nitrous gas, by means of a burning lens.

Rationale...The charcoal at the temperature of ignition decomposes the nitrous gas, by subtracting its oxigen; hence carbonic acid is formed which may be evinced by admitting to the residuary gas, a solution of barytes, strontia, or lime in water.

Experiment XI.

Nitrous gas is absorbed by green muriate, sulphate, and nitrate of iron.

A very concentrated solution of pure green muriate of iron, (prepared by dissolving iron filings perfectly free from rust, in muriatic acid, evaporating the solution briskly, and preserving it from the contact of atmospheric air,) is extremely well calculated to ascertain the quantity of nitrogen gas contained in a given quantity of nitrous gas, in an easy manner.

To prove the absorption of nitrous gas by this means it is only necessary to agitate in a graduated tube a quantity of the gas in contact with the solution; the green solution of iron will soon assume a brown colour, the gas will be diminished, and the solution ascend into the tube.

A solution of pure green sulphate of iron (prepared by dissolving clean iron filings in sulphuric acid, and then agitating the solution in contact with sulphurated hidrogen gas) answers the same purpose. Pale green nitrate of iron may likewise be used with advantage.

Rationale...The absorption of the nitrous gas, by means of these solutions, takes place without any decomposition of it at common temperatures. It depends merely on an equilibrium of affinity produced by the following simple attractions.

1. That of green oxid of iron for the oxigen of nitrous gas and water.

2. That of the hidrogen of the water for the nitrogen of the nitrous gas; and,

3. That of the principles of the sulphuric acid for nitrogen and hidrogen.

Remark...That this is the true cause of the absorption, Professor Davy has sufficiently proved in his Researches, p. 176. Vauquelin and Humbolt have been mistaken with regard to

its nature;* the products they obtained must have arisen from the exposure of their impregnated solution to the atmosphere.

The absorption of nitrous gas by means of these solutions of iron is proportionable to the degree of the concentration of the solution.

Seventy-five cubic inches of concentrated solution of muriate of iron absorb about 18 of nitrous gas. Sulphate of iron absorbs only one half of this quantity; the gas absorbed may be expelled again by heat.

Nitrous gas (according to Davy) is also absorbed by means of white prussiate of iron, in contact with water; by sulphate of tin; sulphate and muriate of zinc at the *minimum* of oxidation; and probably by many other metallic solutions hitherto not tried.

In fact, whenever the metals capable of decomposing water exist in solution at their *minimum* of oxidation, the affinities exerted by them on nitrous gas and water will be such as to produce combinations; the powers of metallic solutions to combine with nitrous gas at common temperatures, as well as to decompose it at higher temperatures, Davy supposes to be probably in the ratio of the affinity of the metallic oxids they contain for oxigen.

Experiment XII.

Decomposition of nitrous gas by nascent hidrogen gas.

When nitrous gas is exposed to wetted iron filings, a diminution of its volume slowly takes place; the iron becomes oxidated and ammonia is formed.

For performing this experiment, wetted iron filings may be exposed on a shallow dish or plate, supported by a stand, to the action of the gas contained in a broad receiver; the vessel con-

* Annales de Chimie tom. 88, p. 187.

taining the iron filings may next be removed by withdrawing it through the water, and the remaining gas may be made the subject of experiment.

This decomposition of nitrous gas is more quickly effected by putting plates of iron into a solution of nitrate of copper.

Rationale...The water in contact with the iron is decomposed by virtue of the affinity subsisting between its oxigen and the iron. Its hidrogen with a portion of oxigen at the same time attracts the nitrogen of the nitrous gas and produces water, ammonia, and nitrous oxid.

Remark...That the iron is not oxidated in this process at the expense of the oxigen of the nitrous gas, becomes obvious when we consider that water is essentially necessary to produce the decomposition; for dry iron filings effect no change whatever in nitrous gas at the usual temperatures.

Alcaline sulphurets moistened with water, put into a vessel filled with nitrous gas, decompose it in a short time, the remaining gas is no longer reddened by the contact of air, the greatest part is nitrous oxid.

Experiment XIII.

Nitrous gas is decomposed by exposure to zinc and water.

When nitrous gas is exposed to a large surface of zinc in contact with water, it will be slowly converted into nitrous oxid; at the same time that ammonia is generated and white oxid of zinc is formed, if the process is suffered to go on for a considerable time.

Rationale...These phenomena depend like the former upon the decomposition of water by the affinities of part of the oxigen and nitrous gas, for its hidrogen to form ammonia and water.

Remark...Zinc placed in contact with water, and confined by mercury, decomposes it, as Davy observed, at common temperatures. But zinc when perfectly dry, does not in the slightest

degree act upon nitrous gas. Van Marum remarked that tin, lead, iron, and mercury were all oxidated by taking the electric spark in contact with nitrous gas. Davy, who has made the greatest number of experiments concerning the nature of nitrous gas, considers the analysis of it by charcoal as affording *data* best calculated for determining the respective quantities of nitrogen and oxigen in a given bulk of nitrous gas, and correcting it by mean calculations derived from the decomposition of nitrous gas by pyrophorus and hidrogen, and its conversion into nitrous oxid, concluded that 100 grains of nitrous gas are composed of 55.95 of oxigen and 44.05 of nitrogen gas; or taking away decimals, of 56. oxigen and 44. nitrogen gas. This estimation agrees very well with the mean proportions of Priestley's experiments. But as Priestley never ascertained the absolute purity of the gas he made use of, and probably employed different kinds, in different experiments, it is impossible to fix on any one, from which accurate conclusions can be drawn.

Lavoisier's estimation of the respective quantities of oxigen and nitrogen gas, entering into the composition of nitrous gas, has been generally adopted. He supposed 64 parts of nitrous gas, to be composed of $43\frac{1}{2}$ of oxigen and $20\frac{1}{2}$ of nitrogen gas The difference between this and Davy's account is very great indeed, but Davy* has pointed out many sources of error in the experiments of this great man concerning the decomposition of nitrate of potash by charcoal, which were fundamental to his account of the composition of this gas.

* Researches chemical and philosophical, 1800, Div. I.

GAZEOUS OXID OF NITROGEN; OR NITROUS OXID.

PART XXVI.

THE combination of nitrogen and oxigen which we considered before under the name of nitrous gas does not constitute the first degree of oxigenation of nitrogen; there is another degree below this. This combination was formerly called dephlogisticated nitrous gas, but now gazeous oxid of nitrogen or nitrous oxid. It was first discovered by Priestley. Its nature and properties have since been investigated (though not very accurately) by a society of Dutch chemists.

Professor Davy has examined with uncommon accuracy the formation and properties of all the substances concerned in its production. He has detected the sources of error in the experiments of Priestley and the Dutch chemists, and to him we are indebted for a thorough knowledge of this gas. We shall therefore exhibit the philosophy of this gazeous fluid as we find it in his researches concerning the nitrous oxid.

SECT. I.

PROPERTIES

OF

GAZEOUS OXID OF NITROGEN.

GAZEOUS oxid of nitrogen exists in the form of permanent gas. A candle burns with a brilliant flame and crackling noise in it; before its extinction the white inner flame becomes surrounded with a blue one. Phosphorus introduced into it, in a state of *actual* inflammation, burns with increased splendor, as in oxigen gas. Sulphur introduced into it when burning with a feeble blue flame is instantly extinguished; but when in a state of *vivid inflammation*, it burns with a rose coloured flame. Ignited charcoal burns in it more brilliantly than in atmospheric air. Iron wire with a small piece of wood affixed to it when inflamed, and introduced into a vessel filled with this gas burns vehemently and throws out bright scintillating sparks. No combustible body however burns in it, unless it be previously brought to a state of vivid inflammation. Hence sulphur may be melted, and even sublimed in it, phosphorus may be liquified in it without undergoing combustion. Nitrous oxid is pretty rapidly absorbed by water that has been boiled; a quantity of gas equal to rather more than half the bulk of the water may be thus made to disappear, the water acquires a sweetish taste, but its other properties do not differ perceptibly from common water. The whole of the gas may be expelled again by heat. It

does not change blue vegetable colours. It has a distinctly sweet taste, and a faint, but agreeable odour. It undergoes no diminution when mingled with oxigen or nitrous gas. Most of the liquid inflammable bodies, such as ether, alcohol, volatile and fat oils, absorb it rapidly and in great quantity. Acids exert but little action on it. The affinity of the neutro-saline solutions for gazeous oxid of nitrogen is very feeble. Green muriate and green sulphate of iron whether holding nitrous gas in solution, or not, do not act upon it. None of the gases when mingled with it, suffer any perceptible change at common temperatures; the muriatic and sulphureous acid gases excepted, which undergo a slight expansion. Alcalies freed from carbonic acid exposed in the dry or solid form have no action upon it; they may however be made to combine with it in the nascent state, and then constitute *saline compounds* of a peculiar nature. These combinations deflagrate when heated with charcoal, and are decomposed by acids; the gazeous oxid of nitrogen being disengaged. It undergoes no change whatever from the simple effect of light. The action of the electric spark for a long while continued, converts it into a gas analogous to atmospheric air and nitrous acid; the same is the case when it is made to pass through an ignited earthern tube. It explodes with hidrogen in a variety of proportions, at very high temperatures; for instance, when electric sparks are made to pass through the mixture. Sulphurated, heavy and light carbonated hidrogen gases, and gazeous oxid of carbon likewise burn with it when a strong red heat is applied. 100 parts by weight of nitrous oxid, contain 36.7 of oxigen and 63.3 of nitrogen; 100 cubic inches weigh 50 grains at 55° temperature and 30 atmospheric pressure. Animals when wholly confined in gazeous oxid of nitrogen, give no signs of uneasiness for some moments, but they soon become restless and then die. When gazeous oxid of nitrogen is mingled with atmospheric air, and then received into the lungs, it generates highly pleasurable sensations; the eff cts it produces on the animal system are eminently distinguished from every other chemi-

cal agent. It excites every fibre to action, and rouses the faculties of the mind, inducing a state of great exhilaration, an irresistible propensity to laughter, a rapid flow of vivid ideas, and unusual vigour and fitness for muscular exertions, in some respects resembling those attendant on the pleasantest period of intoxication, without any subsequent languor, depression of nervous energy, or disagreeable feelings; but more generally followed by vigour, and a pleasurable disposition to exertion, which gradually subsides.

Such are the properties which characterize the nitrous oxid.

The Dutch chemists and some French and German philosophers assert* that it cannot be respired; that burning phosphorus, sulphur, and charcoal are extinguished in it, &c. It is probable they did not examine it in a state of purity, for it is otherwise difficult to account for these and many other erroneous opinions.

METHODS OF OBTAINING GAZEOUS OXID OF NITROGEN.

Gazeous oxid of nitrogen is produced, when substances having a strong affinity with oxigen are brought into contact with nitric acid, or with nitrous gas. It may therefore be obtained by various processes, in which nitrous gas or nitric acid is decomposed by substances capable of attracting the greater part of their oxigen. The most commodious and expeditious, as well as cheapest mode of obtaining it, is by decomposing nitrate of ammonia, *at a certain temperature*, in the following manner.

1. Introduce into a glass retort some pure nitrate of ammonia, and apply the heat of an Argand's lamp; the salt will soon liquify, and when it begins to boil, gas will be evolved. Increase the heat gradually till the body and neck of the retort become

* Gren's Principles of Chemistry, 1800.
Scherer's Introduction to the Knowledge of Gazeous Bodies, 1801.

filled with a semi-transparent milky-white vapour. In this state the temperature of the fused nitrate is between 340° and 480°. After the decomposition has proceeded for a few minutes, so that the gas evolved quickly enlarges the flame of a taper held near the orifice of the retort, it may be collected over water, care being taken during the whole process, never to suffer the temperature of the fused nitrate to rise above 500° Fahr. which may easily be judged of, from the density of the vapours in the retort, and from the quiet ebullition of the fused nitrate; for if the heat be increased beyond this point, the vapours in the retort acquire a reddish and more transparent appearance; and the fused nitrate begins to rise, and occupy twice the bulk it did before. The nitrous oxid, after its generation, is allowed to stand over water, for at least six hours, and is then fit for respiration or other experiments.

RATIONALE...Nitrate of ammonia consists of nitric acid and ammonia; nitric acid is composed of nitrous gas and oxigen; and ammonia consists of hidrogen and nitrogen. At a temperature of about 480° the attractions of hidrogen for nitrogen in ammonia, and that of nitrous gas for oxigen in nitric acid, are *diminished;* while on the contrary, the attractions of the hidrogen of ammonia for the oxigen of the nitric acid, and that of the remaining nitrogen of the ammonia for the nitrous gas of the nitric acid, are *increased;* hence all the former affinities are broken, and new ones produced, namely; the hidrogen of the ammonia attracts the oxigen of the nitric acid, the result of which is *water;* the nitrogen of the ammonia combines with the liberated nitrous gas, and forms *nitrous oxid.* The water and nitrous oxid produced, probably exist in binary combination in the aeriform state, at the temperature of the decomposition.

Such is the philosophy of the production of gazeous oxid of nitrogen, by decomposing nitrate of ammonia at that temperature, given by Davy.

To illustrate this complicated play of affinity more fully, the following sketch may not be deemed superfluous.

DIAGRAM,

EXHIBITING

THE PRODUCTION

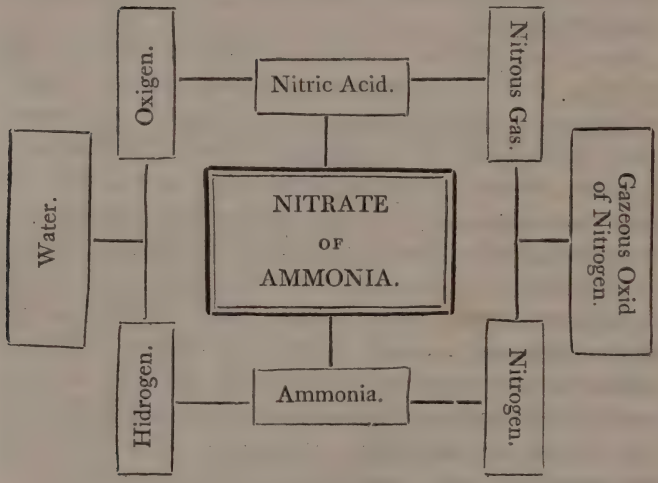
OF

GAZEOUS OXID OF NITROGEN,

BY DECOMPOSING

NITRATE OF AMMONIA,

AT 480° FAHR.



REMARK...Professor Davy has likewise pointed out that when the heat employed for decomposing nitrate of ammonia is raised above the before-stated temperature another play of affinities takes place; the attractions of nitrogen and hidrogen for each

other and of oxigen for nitrous gas are still more diminished, whilst that of nitrogen for nitrous gas is totally destroyed, and that of hidrogen for oxigen increased to a greater extent. A new attraction likewise takes place, namely, that of nitrous gas for nitric acid to form *nitrous vapour*,* and a new arrangement of principles is rapidly produced: the nitrogen of the ammonia having no affinity for any of the single principles at this temperature, enters into no binary compound; the oxigen of the nitric acid forms water with the hidrogen, and the nitrous gas combines with the nitric acid to form *nitrous vapour*.

All these substances most probably exist in combination, at the temperature of their production; and at a lower temperature assume the form of *nitrous acid, nitrous gas, nitrogen*, and *water*; and hence we see the necessity of not heating the nitrate of ammonia above the before-stated temperature.

On account of the rapid absorption of gazeous oxid of nitrogen by water, it is economical to preserve the fluid which has been used to confine this gas, and to make use of it for collecting other quantities of it. In order to hasten its production, the nitrate of ammonia may be previously freed from its water of crystallization by gently fusing it in a glass or Wedgwood's bason for a few minutes, and then keeping it for use in a well-stopped bottle.

2. Nitrous oxid may likewise be obtained by exposing common nitrous gas to alcaline sulphites, particularly to sulphite of potash containing its full quantity of water of crystallization. The nitrous oxid produced from nitrous gas by sulphite of potash has all the properties of that generated from the decomposition of nitrate of ammonia.

RATIONALE...The conversion of nitrous gas into nitrous oxid, by these bodies, depends on the abstraction of a portion of its oxigen by the greater affinity of the sulphite presented to it.

* Hence the reddish vapour in the retort, stated before, page 295.

The nitrogen and remaining oxigen assume a more condensed state of existence, and constitute nitrous oxid.

3. Nitrous oxid may also be obtained by mingling together nitrous gas and sulphurated hidrogen gas. The volume of gases in this case is diminished, sulphur deposited, ammonia, water, and nitrous oxid are formed.

Rationale...The change of principles which takes place in this experiment depends upon the combination of the hidrogen of the sulphurated hidrogen gas, with different portions of the oxigen and nitrogen of the nitrous gas, to form water and ammonia, and to deposit sulphur. The remaining oxigen and nitrogen being left in due proportion constitute nitrous oxid.

Remark...This singular exertion of attractions by a simple body appears highly improbable *a priori*; but the formation of ammonia, and the non-oxigenation of the sulphur, elucidate the fact. In performing this experiment care should be taken that the gases should be rendered as dry as possible; for the presence of water considerably retards the decomposition.

4. Nitrous oxid may also be produced by presenting alcaline sulphurets to nitrous gas. Davy observed that a solution of sulphuret of strontia, or barytes, answers this purpose best.

Rationale...This decomposition of nitrous gas is not solely produced by the abstraction of oxigen from the nitrous gas, to form sulphuric acid. It depends equally on the decomposition of the sulphurated hidrogen dissolved in the solution or liberated from it. In this process, sulphur is deposited and sulphuric acid formed.

5. Nitrous oxid is obtained in many circumstances similar to those in which Nitrous gas is produced. Dr. Priestley found that nitrous oxid was evolved, together with nitrous gas, during the solution of iron, tin, and zinc in nitric acid.

Rationale...It is difficult to ascertain the exact rationale of these processes, for very complicated agencies of affinities take place. Either the nascent hidrogen arising from the decomposition of the water by the metallic substance may combine

with portions of the oxigen and nitrogen of the nitrous gas; and thus by forming water and ammonia, convert it into nitrous oxid; or the metallic substance may attract at the same time oxigen from the water and nitrous gas, whilst the nascent hidrogen of the water seizes upon a portion of the nitrogen of the nitrous gas, to form ammonia. The analogy between this process and the decomposition of nitrous gas by sulphurated hidrogen render the first opinion most probable.

Such are the principal methods of obtaining nitrous oxid. There are no reasons, Davy thinks, for supposing that nitrous oxid is formed in any of the processes of nature, and the nice equilibrium of affinity by which it is constituted forbids us to hope for the power of composing it from its simple principles. We must be content to produce it artificially.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF GAZEOUS OXID OF NITROGEN.

Experiment I.

Gazeous oxid of nitrogen is rapidly absorbed by water.

Fill a glass cylinder or graduated tube with water previously boiled, and invert it in a bason of the same fluid. Having done this send up into it a quantity of nitrous oxid, and mark the level of the water in the cylinder. Then agitate it for a few minutes in the water, and the bulk of the gas will be seen considerably diminishing. Water may thus be made to absorb about one half of its own bulk of gazeous oxid of nitrogen.

On boiling the water, the gas which was absorbed will be liberated, possessing all its former properties.

If nitrous oxid be repeatedly exposed to water, the residual gas will be the common air previously contained in the water and from which it can in no case be perfectly freed by ebullition; this air becomes separated on account of the greater affinity of water for nitrous oxid. The quantity of common air thus produced generally amounts to about $\frac{1}{10}$ part of the volume of water.

The absorption of nitrous oxid by the inflammable fluids enumerated before may be evinced in a similar manner.

Experiment II.

Combustible bodies do not burn in gazeous oxid of nitrogen, except when in a state of actual inflammation.

Fill a jar over mercury with gazeous oxid of nitrogen, and keep it over that fluid; introduce into it a small piece of sulphur, camphor, or phosphorus, and touch these substances with a bent wire heated to a *dull redness*. The sulphur, camphor, or phosphorus will melt, and on continuing the heat may even be made to sublime in the gas, but no accension will take place.

But that the gas is capable of maintaining the combustion of inflammable substances becomes evident from the following facts:

Experiment III.

Combustion of the taper in gazeous oxid of nitrogen.

Immerse a lighted taper into a jar filled with nitrous oxid. The flame of the taper will become instantly larger, it will first burn with a brilliant white flame and sparkle as in oxigen gas. As the combustion goes on, the lustre of the flame diminishes; it gradually lengthens and becomes surrounded with a pale blue cone of light, from the apex of which much unburnt charcoal is thrown off in the form of smoke. The flame continues double to the end of the process.

Experiment IV.

Combustion of phosphorus in gazeous oxid of nitrogen.

Put a piece of phosphorus of the size of a pea into a copper ladle, set fire to the phosphorus with a match, and quickly intro-

duce it into a jar filled with the gas. The phosphorus will continue to burn with a splendor nearly equal to that in oxigen gas.

The accension of phosphorus may likewise be evinced in the following manner:

Experiment V.

Fill a strong glass cylinder over mercury, one-eighth full of gazeous oxid of nitrogen; send up into it a few grains of phosphorus, heat a bent iron wire *white-hot*, and introduce it quickly through the mercury to touch the phosphorus, which thus will take fire instantly with a considerable detonation.

Remark...This experiment requires caution, the cylinder in which the phosphorus is inflamed should be very strong. The gazeous oxid employed should not exceed one-eighth of the capacity of the jar. The wire for the inflammation ought to be very well curved so as to be expeditiously introduced into the jar and capable of being quickly withdrawn. We have witnessed several accidents where the detonating jar burst during this experiment.

Another very successful method is as follows:

Experiment VI.

Let the jar containing the gazeous oxid of nitrogen be placed over mercury; introduce the phosphorus in a small tube containing oxigen gas, so balanced as to swim on the surface of the mercury without communicating with the gazeous oxid. The phosphorus is then fired in the oxigen gas, with an ignited iron wire, by which at the moment of combustion, the tube containing it must be raised into the gazeous oxid, and thus the combustion continues.

Experiment VII.

Sulphur burning with a feeble blue flame, becomes instantly extinguished in gazeous oxid of nitrogen.

Put a piece of sulphur into a copper ladle, set fire to it, by means of a candle, and when it begins to burn with a blue feeble flame introduce it into a jar filled with gazeous oxid of nitrogen. The sulphur will be extinguished the instant it is plunged into the gas.

But that sulphur may be made to burn in it, becomes obvious from the following

Experiment VIII.

Sulphur in a state of vivid inflammation burns with a rose-coloured flame in gazeous oxid of nitrogen.

Dip a slip of copper into melted sulphur; when cold set fire to it, and when in an actual state of combustion introduce it into a jar filled with the gas, it will continue burning with a beautiful flame very much enlarged and of a vivid rose-colour.

This experiment may be more accurately performed in the same manner as the inflammation of phosphorus; namely, by introducing it into the small vessel filled with oxigen gas and igniting it by means of the heated wire.

Experiment IX.

Detonation of gazeous oxid of nitrogen with carbonated hidrogen gas.

Nitrous oxid and carbonated hidrogen gas possess no action on each other, except at high temperatures. But when mingled to-

gether in certain proportions and exposed to the electric spark, a new arrangement of their principles takes place. This may be proved in the following manner:

Mingle together in a detonating tube, 35 parts of gazeous oxid of nitrogen and 15 of carbonated hidrogen gas. On passing the electric spark through it, the inflammation will be very vivid, and the light produced, bright red. After the explosion the space occupied by the gases will be about 60.

When 22 parts of nitrous oxid and 20 of hidro-carbonate are exploded, the residue fills a space equal to 45.

If strontia water be brought into contact with the gas after the detonation, a white precipitate is instantly formed and a diminution takes place. On presenting nitrous gas to this residue, the gas again becomes diminished.

RATIONALE...Reasoning from analogy there can be little doubt, but that when carbonated hidrogen gas is inflamed with excess of gazeous oxid of nitrogen, it will be only partially decomposed or converted into nitrogen, nitrous acid, and atmospheric air.

EXPERIMENT X.

Gazeous oxid of nitrogen and phosphorated hidrogen gas, detonate likewise.

Phosphorated hidrogen gas and gazeous oxid of nitrogen exert no action upon each other at common temperatures, but that they may be made to act upon each other at a very high temperature, the following experiments will prove.

1. Mix 10 grain measures of phosphorated hidrogen gas and 52 of gazeous oxid of nitrogen, in a graduated detonating tube, and pass the electric spark through it. A very vivid inflammation will take place, and the tube will be filled with white vapour. The volume of the gas left behind will fill a space nearly equal

to 60. On agitating this fluid in contact with water no absorption will take place. On admitting nitrous gas a diminution ensues.

RATIONALE...It appears from this experiment that when a small quantity of phosphorated hidrogen gas is inflamed with gazeous oxid of nitrogen, both the phosphorus and hidrogen are consumed; whilst the super-abundant gazeous oxid, is converted into nitrous acid, and atmospheric air, by the ignition; or a certain quantity is partially decomposed into atmospheric air by the combination of a portion of its oxigen with the combustible gas.

2. Twenty-five parts of gazeous oxid of nitrogen mingled with 10 of phosphorated hidrogen gas, may likewise be inflamed. After the detonation white dense vapours become visible, and the gas left occupies a space equal to 25. The residuary gas is not absorbable by water; on admitting a solution of green sulphate of iron, or prussiate of potash, no blue or green precipitate is produced, but if 25 parts of nitrous gas are mingled with it, the result will be 50.

RATIONALE...From this experiment we learn that when phosphorated hidrogen gas and gazeous oxid are to each other as 25 to 10, they both disappear, whilst nitrogen is evolved, and water and phosphoric acid produced. Reasoning concerning the composition of gazeous oxid of nitrogen from this result, we should conclude that it was composed of about 38 oxigen and 62 nitrogen.

3. Ten grain-measures of gazeous oxid, mingled with 20 of phosphorated hidrogen gas cannot be inflamed.

4. Twenty-five of gazeous oxid of nitrogen with 20 of phosphorated hidrogen gas inflame readily. The gas after detonation is likewise opaque, and fills a space equal to about 45. The residue is not miscible with water, no white fumes are produced by admitting oxigen gas.

RATIONALE...Here we are taught that the affinity of phosphorus for the oxigen of gazeous oxid of nitrogen, is stronger than

that of hidrogen at the temperature of ignition; so that when phosphorated hidrogen gas is mingled with a quantity of gazeous oxid of nitrogen, not containing sufficient oxigen to burn both its constituent parts, the phosphorus only is consumed and the hidrogen is liberated.

Experiment XI.

Combustion of charcoal in gazeous oxid of nitrogen.

This experiment is best performed by introducing a small piece of charcoal into a jar filled with nitrous oxid, confined by mercury, and then applying the focus of a burning-lens. The charcoal will thus take fire and burn vividly.

It may likewise be performed by fixing a piece of well-burnt charcoal to a copper wire, igniting the charcoal completely and introducing it into the gas.

Experiment XII.

Combustion of iron in gazeous oxid of nitrogen.

The experiment may be performed in a manner similar to the combustion of iron in oxigen gas, p. 191, or more accurately, by setting fire to the touch-wood affixed to the wire by means of a burning-glass.

Experiment XIII.

Combustion of zinc in gazeous oxid of nitrogen.

Take shavings of zinc, form them into a ball, in the middle of which a piece of phosphorus must be included; affix the ball of zinc shavings to a copper wire, set fire to the phosphorus, and introduce it into a receiver filled with the gas. The zinc

will thus be made to burn with a beautiful white flame surrounded by a green one, and dense white vapours of oxid of zinc will fill the receiver.

Experiment XIV.

Accension of pyrophorus in gazeous oxid of nitrogen.

Pyrophorus, which readily inflames in nitrous gas (as we have seen before, experiment VIII. p. 285,) and in atmospheric air at a low temperature, requires for its combustion in nitrous oxid, a much greater degree of heat. It will not burn in it even at 212°. In order to inflame pyrophorus in gazeous oxid of nitrogen over mercury, the wire must be strongly heated, but not ignited. The pyrophorus then takes fire, and burns with a splendid white light, greatly resembling that produced in oxigen gas.

INFERENCES.

From the preceding experiments it becomes evident that the inflammable bodies in general require for their combustion in gazeous oxid of nitrogen, much higher temperatures than those in which they burn in oxigen gas or atmospheric air. When intensely heated, they decompose it with the production of much heat and light, and become oxigenated. During the combustion of solid or fluid bodies producing flame in it, nitric acid is generated, and that probably from a new arrangement of principles analogous to those stated before. Likewise when gazeous oxid of nitrogen in excess is decomposed by inflammable gases, nitrous acid, and sometimes a gas analogous to common air is produced, doubtless from the same cause.

Pyrophorus is the only body that inflames in gazeous oxid of nitrogen below the temperature of ignition.

Phosphorus burns in it with a blue flame, probably forming with it only phosphorous acid a little above a dull red heat; but when heated more intensely, phosphoric acid is produced.

Charcoal, sulphur, iron, and the compound inflammable bodies decompose this gas, only at temperatures equal to, or above that of ignition, probably each at a different temperature.

The double flame produced during the combustion of charcoal, depends on the production of nitrous acid formed during the process; for it may be produced by plunging the taper into common air containing nitrous acid vapour or in a mixture of gazeous oxid of nitrogen and nitrogen gas, through which nitrous acid has been diffused. It is never perceived in the combustion till much nitrous acid is formed.

If a taper be suffered to burn in a mixture of equal parts of gazeous oxid of nitrogen and nitrogen gas, it burns at first with a flame nearly the same as that of a candle in common air, whitish yellow. Before its extinction the interior white flame and exterior blue one are perceived.

Nitrous oxid is therefore a gas unalterable in its constitution at temperatures below ignition. It is composed of oxigen and nitrogen, existing most probably in the most intimate union which those substances are capable of assuming. For it is unalterable by those bodies which are capable of attracting oxigen from nitrous gas, and nitrous acid at common temperatures. The properties of nitrous oxid approach to those of acids.

AMMONIA,

OR

AMMONIACAL GAS.

PART XXVII.

SECT. I.

THIS gas was first discovered by Dr. Priestley. It is composed of hidrogen and nitrogen rendered gazeous by the addition of caloric.

PROPERTIES OF AMMONIA.

Ammonia gas has a strong and very pungent odour. It extinguishes flame, yet it increases the magnitude of the flame of a taper before extinction, producing a pale yellow colour round its edge. Animals cannot breathe it without death ensuing. It is lighter than atmospheric air, in the proportion of three to five. It tinges yellow vegetable colours brown, and blue ones green. It is rapidly absorbed by cold water; by ardent spirit, essential oils, ether, charcoal, sponge, bits of linen cloth, and all porous bodies.

When a piece of ice is brought in contact with this gas, it melts and absorbs the gas, while at the same time its temperature is diminished. It has no effect upon oxigen gas while cold; but when made to pass with it through an ignited tube, it detonates and becomes decomposed. The same is the case with common air. It is also decomposed by phosphorus at high temperatures.

It does not explode when mixed with hidrogen gas. Nitrogen gas has no effect upon it. Atmospheric air does not combine with it at common temperatures, but only mixes with and dilutes it. When made to pass through ignited charcoal it forms with it a substance called prussic acid. If brought into contact with acid gases, both gases lose their gazeous form and become concrete. It has no sensible action on earths or on the *salino-terrene* substances. It combines readily with acids, and unites to sulphur when both are in a state of vapour. It reduces oxids of metals to their metallic state, and is decomposed by them. It is also decomposed by electrization and by oxigenated muriatic acid gas, &c. When exposed to the temperature of — 46° it crystallizes, and when suddenly cooled down to — 68° it assumes a gelatinous appearance, and has scarcely any odour.*

METHODS OF OBTAINING AMMONIA.

1. Mix together equal quantities of muriate of ammonia and quick-lime, separately powdered; introduce them into a gas-bottle or retort, apply the heat of a lamp, and receive the gas over mercury.

RATIONALE...Muriate of ammonia consists of muriatic acid and ammonia; on adding lime to it a decomposition takes place, the muriatic acid quits the ammonia and unites to the lime, in order to form muriate of lime which remains in the retort, and the ammonia flies off in the state of gas.

* Fourcroy and Vauquelin, *Ann. de Chim.* XXIX. p. 289.

Remark...In order to obtain the gas in a state of purity, it is essentially necessary that a considerable quantity of the gas first disengaged, be suffered to escape, on account of the common air contained in the distilling vessel, and in the interstices of the ingredients.

2. Ammonia may likewise be obtained by heating the liquid ammonia of the shops (water of pure ammonia, *Pharm. Lond.)* in a retort placed in communication with the mercurial pneumatic trough.

Rationale...The ammonia contained in this liquid combines with caloric, assumes the form of ammoniacal gas, and parts with the water to which it was united.

Remark...The temperature of the fluid must not be carried so high as to cause the water to be converted into vapour, or, if this cannot well be avoided, a small vessel should be interposed between the retort and the receiver which when kept cool may serve to condense the aqueous vapour which is formed and cause the ammoniacal gas to pass in a very pure and dry state.

Ammonia is likewise produced during the spontaneous decomposition of animal and vegetable substances; in these cases it did not pre-exist in them ready formed, but is generated by the union of the hidrogen and nitrogen contained in them.

SECT. II.

EXPERIMENTAL PROOFS

OF

THE PROPERTIES OF AMMONIA.

Experiment I.

Ammonia is absorbed by water, ardent spirit, &c.

INTRODUCE into a jar filled with ammonia standing over mercury, a little water, ardent spirit, or a bit of moistened sponge, paper, &c. In whichever manner the experiment is made, there will be an absorption; the gas becomes absorbed, and the mercury rises in the jar so as to fill it entirely, provided the gas be sufficiently pure.

If water be presented to this gas in the state of ice, it melts rapidly.

Remark...Water which has absorbed the gas acquires its peculiar odour, and constitutes what is called liquid ammonia, or more properly, solution of ammonia in water. From this solution the gas may be again liberated by heat.

Experiment II.

Ammonia extinguishes light, but increases the magnitude of the flame before its extinction.

A burning taper dipt several times successively into a bottle filled with ammonia is extinguished every time, but before its

extinction the flame is enlarged by the addition of another one of a pale yellow colour, and at length this light flame will extend from the top of the vessel to the bottom. If the lighted taper be only presented to the mouth of a vessel filled with ammonia, the yellowish flame will rise considerably higher than that of the taper.

Experiment III.

Ammonia is lighter than atmospheric air.

Let a jar filled with ammonia be placed with its mouth upwards, and left in that situation for a few minutes, it will be found to have exchanged its contents for common air, which being heavier descends and displaces the gas.

Experiment IV.

Ammonia is heavier than hidrogen gas.

Put a quantity of hidrogen gas into a long tube; add to it half the quantity of ammonia, and to this a like quantity of muriatic acid gas. The two later gases will combine and form a white cloud (muriate of ammonia;) but the cloud will not rise within the space occupied by the hidrogen gas; consequently the latter had kept its place below the other without mixing with it.

That the ammonia is lighter than the muriatic acid gas is shown from the formation of the white cloud on their mixture; for it begins at the bottom and gradually reaches the top when the muriatic acid gas is last added; but when the ammonia is presented to the muriatic acid gas the whole becomes cloudy immediately.

Experiment V.

Ammonia tinges yellow vegetable colours brown; and blue ones green.

This may be shown by pasting a piece of paper coloured yellow with turmeric, or blue with cabbage-juice, into the top of a

receiver, and exposing it to the action of the gas. The first will soon become brown and the latter green.

The same effect may be produced by holding the papers over a bottle filled with water impregnated with ammonia.

Experiment VI.

Carbonic acid gas and ammonia readily unite and form carbonate of ammonia.

Fill a vessel with carbonic acid gas over mercury, and add ammonia; a white vapour will instantly be formed, heat becomes evolved, the gases disappear, and carbonate of ammonia crystallizes on the inside of the vessel.

Experiment VII.

Ammonia becomes decomposed by oxigenated muriatic acid gas, at common temperatures.

Mix in a receiver over mercury two parts of oxigenated muriatic acid gas with one part by measure of ammonia. When these two bodies come in contact, a brisk detonation is produced accompanied with a yellowish light; the two gases decrease in volume, and there is formed a portion of solid matter (muriate of ammonia) which adheres to the sides of the vessel. The gas which remains has no odour like ammonia, nor colour like muriatic acid gas. It is not dissolved in water, nor does it maintain combustion; it is therefore nitrogen gas. In the bottom of the vessel there is found a clear and transparent liquid, which is water holding a certain quantity of the muriate of ammonia in solution.

Rationale...Ammonia consists of nitrogen and hidrogen dissolved in caloric. Oxigenated muriatic acid gas consists of muriatic acid, oxigen and caloric. On bringing these two gases into contact a reciprocal decomposition takes place. The oxigen of

the oxigenated muriatic acid gas combines with the hidrogen of the ammonia and forms water; while the nitrogen, the other component part of the ammonia, becomes disengaged. The oxigenated muriatic acid gas having lost its oxigen becomes converted into simple muriatic acid gas, part of it unites to part of the ammonia, (which in this experiment is present in too large a quantity to be wholly decomposed) and forms with it muriate of ammonia. The explosion, heat, and light originate from the liberated caloric which kept the gases in their aeriform state.

Remark...If a smaller portion of ammonia is added to the above quantity of oxigenated muriatic acid gas, its decomposition will be complete, and no muriate of ammonia be produced. The results then are only *muriatic acid* and *water*.

The same facts may be shown in the following manner:

Experiment VIII.

Fill four-fifths of a long glass tube with strong oxigenated muriatic acid, and the remaining fifth with water strongly impregnated with ammonia, and invert it in a saucer of water. The ammonia on account of its lightness will pass through the oxigenated muriatic acid, but by thus passing a strong effervescence is produced, the elastic fluid by which it is occasioned collects itself in the upper part of the tube, and a portion diffuses itself in the vessel. The gas disengaged will be found to be nitrogen gas.

Rationale...The explanation of this experiment is analogous to the former.

Experiment IX.

Decomposition of ammonia by means of black oxid of manganese at a high temperature.

If ammonia be made to pass over pounded black oxid of manganese brought to a red heat in a Wedgwood's tube, connected, by

means of another tube, with an empty bottle immersed in cold water or ice, abundance of red vapours will soon be produced, and these will be succeeded by white ones, condensing in the bottle into a bright transparent fluid, which has a pungent saline odour. If this liquid be distilled to dryness by a gentle heat the product will be water. The residue in the retort is of a white colour. It fuses in the fire, detonates on ignited coals; and produces vapours of nitric acid by the affusion of sulphuric acid; or ammonia when saturated with lime. It is therefore nitrate of ammonia. The black oxid of manganese has changed its colour; being turned to a pale brown, and no longer gives oxigen gas by the addition of heat.

Rationale...In this experiment the hidrogen of the ammonia unites to part of the oxigen given out by the black oxid of manganese and forms water. The nitrogen of the ammonia unites to another part of the oxigen and produces nitric acid, this joins to a quantity of undecomposed ammonia and forms nitrate of ammonia.

Experiment X.

Decomposition of ammonia by electrization.

For this purpose take a detonating tube, admit into it about a cubic inch of ammonia, and pass through it a succession of electric discharges. When about 200 strong shocks have traversed the gas it will have increased to three times its original bulk. On admitting a small quantity of water the gas will not as before be completely absorbed by this fluid, but a part will remain. Hence it appears that the gas has undergone a decomposition, and on examination it will be found that the chemical union of the hidrogen and nitrogen has been broken, and that that they are only mechanically mixed.

SULPHUREOUS ACID GAS.

PART XXVIII.

SEVERAL philosophers have paid attention to the properties of this gas and its combinations; but Berthollet was the first who published an accurate account of it, which Fourcroy and Vauquelin, have lately investigated still more completely. Their paper (of which we have made use) is inserted in the *Annales de Chimie*, II. 54, and copied into *Nicholson's Journal, vol.* I. *p.* 313.

We have seen before, p. 189, that when sulphur is united to oxigen it forms an acid. When the quantity of oxigen is sufficient to oxigenate a given quantity of sulphur completely, the result is a perfect acid called sulphuric acid. We shall now see that if a less quantity of oxigen is made use of, the result is an imperfect acid, capable of taking the gazeous state. To this gazeous fluid we give the name of sulphureous acid gas. It becomes obvious from this, that sulphureous acid gas, has the same relation to sulphuric acid, as phosphorous acid has to the phosphoric acid. At least this gas occupies the middle place between sulphur and sulphuric acid, which will be more evident when we shall speak of the formation of acids.

SECT. I.

PROPERTIES
OF
SULPHUREOUS ACID GAS.

SULPHUREOUS acid gas is a permanently elastic aeriform fluid at the ordinary pressure and temperature of our atmosphere. Its odour is strong and suffocating. It cannot maintain combustion, nor the respiration of animals. Its weight is more than double that of atmospheric air. Its specific gravity according to Bergman is 0.00246, and 0.00251, according to Lavoisier. It is not inflammable. One hundred cubic inches of it weigh nearly 63 grains. It is composed, according to Fourcroy, of 85 sulphur and 15 oxigen. It is acid; it first reddens and then destroys the greater part of the vegetable colours. It exerts little action on the metals, and has a weak attraction to alcalies and earths. It has the property of whitening silk and giving it a lustre. Priestley, Bergman, Berthollet, &c. say that at high temperatures it deposits sulphur, but Fourcroy and Vauquelin, in consequence of some new experiments, deny this assertion. Phosphorus has no action upon it. Its attraction for oxigen when dry, at the common temperature is very feeble, but if the smallest quantity of moisture be present the union of the two gases is much favoured. At high temperatures the combination is more speedily effected. When a mixture of sulphureous acid gas and oxigen gas is made to pass through an ignited tube,

the two gases combine and sulphuric acid is formed. When passed into water cooled down to the freezing point, the union is very rapid. Water cooled to 40 degrees absorbs one third part of its weight of sulphureous acid gas. It speedily melts ice. Water saturated with it may be frozen without parting with its gas; but when water which has been saturated with it, is exposed to heat, it is filled with a vast number of bubbles which continually increase and rise to the surface; these bubbles are the gas separating from it. It is absorbed by oil, ether, and sulphuric acid, the latter when saturated with it acquires the property of smoking when exposed to air; its colour is altered to a yellowish brown, and its odour is penetrating like that of the gas. When the acid thus saturated with the gas is exposed a few degrees below the freezing point, it congeals or freezes into a crystalline mass. The same happens when submitted to distillation. It decomposes nitric and oxigenated muriatic acid, and dissolves camphor. Sulphureous acid gas and hidrogen gas have no action upon each other at common temperatures, but if they are passed through an ignited tube, a decomposition is effected. Charcoal likewise decomposes sulphureous acid gas at a high temperature. Monge and Clouet affirm that by extreme artificial cold and a strong pressure exerted at the same time, they rendered sulphureous acid gas fluid.

METHODS OF OBTAINING SULPHUREOUS ACID GAS.

1. Take one part of mercury and four of concentrated sulphuric acid; put them into a glass retort connected with the pneumatic quicksilver-trough and apply the heat of a lamp to the mixture till it boils. On continuing the heat after the mercury has been acted upon, sulphureous acid gas will be obtained in abundance.

RATIONALE...In this case a partial decomposition of the sulphuric acid takes place. The mercury abstracts part of its oxigen

and becomes converted into an oxid; the sulphuric acid in consequence of the loss of oxigen, becomes converted into sulphureous acid, which takes the gazeous form at the common temperature.

2. Sulphureous acid gas may likewise be obtained by the slow combustion of sulphur.

Put pounded sulphur into a shallow earthen dish or crucible; melt and set fire to it; and when it is completely inflamed cover it with a large bell-glass perfectly dry; remove the whole on a dish and surround the apparatus with mercury. The sulphur will burn for some time, and the bell-glass will be filled with white vapour. When the vapour has subsided, the gas may be transferred as usual.

RATIONALE...During the burning of the sulphur in a confined quantity of atmospheric air, it absorbs the oxigen contained in it; this however not being sufficient to oxigenate the sulphur completely, the result is an imperfect aeriform acid, or sulphureous acid gas.

3. Sulphureous acid gas may also be obtained by decomposing sulphite of potash or soda, either by heat alone, or by the affusion of acids.

4. If charcoal be moistened with sulphuric acid, and then exposed to distillation, the products are carbonic acid gas and sulphureous acid gas.

RATIONALE...During this operation the charcoal attracts part of the oxigen of the sulphuric acid and forms carbonic acid gas. The sulphuric acid is therefore partly de-oxidated and becomes converted into sulphureous acid gas.

5. Sulphureous acid gas is likewise formed by distilling sulphur with the oxids of mercury, lead, tin, manganese, &c.

RATIONALE...In these processes the sulphur attracts the oxigen of the metallic oxids and becomes converted into sulphureous acid gas, while the oxids are partially restored to the metallic state.

SECT. II.

EXPERIMENTAL PROOFS

OF

THE PROPERTIES OF SULPHUREOUS ACID GAS.

Experiment I.

Sulphureous acid gas is heavier than atmospheric air; and will not maintain combustion.

THIS may be shown by dipping a lighted candle many times successively into a jar filled with this gas. The candle will be extinguished every time, though the jar filled with it, continues exposed to the air.

Experiment II.

Sulphureous acid gas is rapidly absorbed by water.

Fill a cylinder with the gas over mercury, and send up into it a little water. The gas will instantly become diminished, and the mercury will rise up in the vessel.

The absorption of this gas may likewise be shown by dipping the neck of the retort, in which it is disengaged, into a bason of cold water.

Remark...The combination of sulphureous acid gas with water cooled artificially, takes place with such rapidity that not a

single bubble of it rises to the top until the water is saturated. If ice be present in the water it melts rapidly. The water at this temperature increases almost one seventh part in weight.

The saturated water when exposed to a temperature of about 65° or 70° Fahr: becomes filled with a multitude of small bubbles, which continually increase and rise to the surface. This may be shown in the following

Experiment III.

Disengagement of sulphureous acid gas from water saturated with it.

Take a bottle filled with water completely saturated with sulphureous acid gas at a low temperature, plunge it into a bason of hot water and uncork it, an infinite number of small bubbles will instantaneously be extricated, the water in the bottle will appear to boil with great rapidity and lose most of its gas.

Rationale...The sulphureous acid gas contained in the water is capable of remaining in combination with this fluid at low temperatures; but, by the addition of caloric, becomes converted into the state of gas, which flies off and occasions the apparent ebullition.

Remark...Water that has absorbed sulphureous acid gas is to be looked upon as liquid sulphureous acid. It possesses the peculiar odour of the gas and an acid taste. At first it only reddens blue vegetable colours, but at last totally destroys them. The infusion of rose-leaves and several other vegetable pigments lose all their colour by it instantly.

Experiment IV.

Sulphureous acid gas and oxigen gas do not act upon each other at a low temperature, without the intervention of a fluid.

To two parts of sulphureous acid gas, prepared in the mercurial apparatus, add one part of oxigen gas, no perceptible

union will take place even after some months: but if a small quantity of water be added to the mixture an absorption takes place, the volume of the gases becomes diminished, and sulphuric acid is formed.

Remark...The water presented acts as an intermediate body to favour the union of the two gases. Its great attraction for the sulphureous acid gas enables the oxigen to unite to it in order to convert it into sulphuric acid.

Experiment V.

Sulphureous acid gas and oxigen gas readily act upon each other at high temperatures.

In the last experiment we have seen that the two gases have no action upon each other at common temperatures, unless by the intervention of water; but if we transmit a mixture of sulphureous acid gas and oxigen gas through an ignited earthen tube placed across a furnace, very dense white fumes are formed, which become converted into liquid sulphuric acid, and may be collected in a vessel placed for that purpose at the other extremity of the tube.

Rationale...The oxigen gas at this temperature yields its oxigen to the sulphureous acid gas and converts it into perfect sulphuric acid, which it is only capable of doing in a direct manner at that temperature.

Experiment VI.

Hidrogen gas has no action upon sulphureous acid gas in the cold, but decomposes it at high temperatures.

When we mingle together hidrogen gas and sulphureous acid gas at common temperatures, there is no action; but if we trans-

mit a mixture of three parts of hidrogen gas and one of sulphureous acid gas, through a Wedgwood's tube in a state of ignition, sulphurated hidrogen gas will be evolved, and sulphur deposited at the extremity of the tube, opposite to that through which the gas is made to pass.

RATIONALE...Part of the hidrogen at such a temperature unites to the oxigen of the sulphureous acid gas to form water, the sulphur is consequently left uncombined; another part (or at least the excess) of the hidrogen dissolves a portion of the sulphur and becomes converted into sulphurated hidrogen gas.

REMARK...The two last experiments are well calculated to demonstrate the nature of sulphureous acid gas. In the first, it became changed into sulphuric acid by the addition of oxigen at a high temperature. In the other, hidrogen gas decomposes the sulphureous acid gas, at the same temperature, by taking from it that portion of oxigen which kept it acid, and the sulphur is disengaged.

EXPERIMENT VII.

Formation of sulphate of ammonia by mingling sulphureous acid gas and ammoniacal gas.

Let sulphureous acid gas be mixed with ammoniacal gas over mercury, a beautiful white cloud will be formed by their combination, heat is liberated and both gases gradually assume the solid state, forming sulphate of ammonia. If the gases have been pure the mercury rises almost to the top of the vessel.

If the sulphureous acid gas be presented to the ammoniacal gas the cloud is formed at the bottom, and gradually rises to the top; but if the ammoniacal gas be poured in last, the cloud rises immediately to the top. These consequences naturally result from the ammoniacal gas being the lightest.

RATIONALE...The white cloud formed in this experiment is sulphate of ammonia, which originates from the strong attraction

these gases have for each other. The caloric which kept them in the gazeous state being set free produces the heat evolved during this union.

Experiment VIII.

Sulphuric acid saturated with sulphureous acid gas acquires a concrete form.

When sulphureous acid gas is made to pass into sulphuric acid cooled by a frigorific mixture, the gas is for a considerable time absorbed by the acid, which at last acquires a solid form. The solid acid has no very perceptible odour. If part of it be laid upon a plate of glass it exhibits an effervesence like that occasioned by the decomposition of carbonate of lime by the affusion of a weak acid. It soon afterwards becomes liquid and very odorous.

Remark...We have therefore a concrete sulphuric acid formed by the addition of sulphureous acid gas. Nitrous gas is also said to possess the same property. There is no doubt but that other concrete modifications occasioned by other gases will be discovered hereafter.

Experiment IX.

Decomposition of sulphureous acid gas by charcoal.

When sulphureous acid gas is passed through a tube containing ignited charcoal, carbonic acid gas and sulphurated hidrogen gas are obtained, and the inner surface of the tube is lined with sulphur.

Rationale...The charcoal at the temperature of ignition takes the oxigen from the sulphureous acid gas and forms with it

carbonic acid gas; the sulphur therefore becomes precipitated. The sulphurated hidrogen gas arises from a portion of water contained in the charcoal.

Experiment X.

Decomposition of sulphureous acid gas by muriate of tin.

Fill a cylinder with sulphureous acid gas, and pass up into it some *fresh prepared* concentrated muriate of tin, the volume of the gas will soon become diminished and sulphur be deposited.

Rationale...The muriated oxid of tin robs the sulphureous acid gas of its oxigen, and becomes converted into oxigenated muriate of tin, and the sulphur deprived of its oxigen is deposited.

MURIATIC ACID GAS.

PART XXIX.

SECT. I.

THE basis of this gas is still unknown. The presence of oxigen has not been even demonstrated in it, and it is only by analogy that we may venture to suppose it instrumental in this acid gas.

PROPERTIES OF MURIATIC ACID GAS.

Muriatic acid gas has a very pungent and suffocating odour, which excites coughing. It is readily absorbed by water, by ardent spirit, ether, fat and essential oils, melted wax, phosphorus, and many other bodies. It is a true acid. It suffocates animals, and is so very caustic as to excoriate the skin. It extinguishes a lighted taper, the flame of which becomes green, or rather light blue, at the upper part of its disk. Light has no effect upon it. Caloric rarefies it. It is heavier than common air. The specific gravity of the former is to that of the latter as

1.750 to 1.000. When brought into contact with atmospheric air, or oxigen gas, it forms a white cloud. Ice is melted by it as speedily as if thrown into the fire. It unites to alcaline and terrene substances, and forms with them new compounds. It has no action on siliceous earths. It combines with alumine and magnesia. It absorbs oxigen, when in the state of gas, feebly, though there are methods of uniting them readily. If ammonical gas be mixed with it and heat applied, both gases lose their gazeous form in a moment, and are transformed to a concrete salt. Carbonic acid gas, nitrogen gas, gazeous oxid of nitrogen, sulphurated hidrogen gas, and carbonated hidrogen gas have no action upon it. It has never been found in a disengaged state in nature. When electric explosions are made to pass through it, its bulk is diminished and hidrogen gas is evolved. These changes are owing to a quantity of water contained in the gas, and cease when it is deprived of moisture, as has been proved by Mr. Henry*

METHODS OF OBTAINING MURIATIC ACID GAS.

1. Muriatic acid gas may be obtained by decomposing muriate of soda by means of sulphuric acid. For this purpose, put into a tubulated retort two parts of very dry muriate of soda and pour on it gradually one part of concentrated sulphuric acid. A violent action takes place and muriatic acid gas becomes liberated, which must be collected over mercury in the usual manner.

RATIONALE...The sulphuric acid has a greater affinity for the soda, than the muriatic acid has, it therefore unites to it and forms sulphate of soda. The muriatic acid being liberated, takes the gazeous form, and appears as muriatic acid gas.

REMARK...As this decomposition takes place very rapidly, it is not necessary to apply heat, until the disengagement of the

* Nicholson's Journal, vol. IV. p. 209.

gas begins to slacken, after which the further extrication may be assisted by the heat of a lamp.

2. Muriatic acid gas may likewise be obtained by expelling it from its combination with water.

For this purpose put concentrated muriatic acid into a retort, immerse the beak of it under a receiver placed in a mercurial pneumatic trough, and filled with that metal. On exposing the acid to a gentle heat muriatic acid gas will be obtained. If the process be very carefully managed nothing but water remains in the retort.

3. Muriatic acid gas is likewise produced by putting any quantity of liquid muriatic acid into a long glass tube, and adding to it about one-third or one-fourth by measure of concentrated sulphuric acid. A violent effervescence takes place, and the whole tube becomes filled with dense white vapours, which are muriatic acid gas, condensed again by means of the moisture in the atmosphere. The sulphuric acid added to the muriatic acid deprives the latter of part of its water, a combination and penetration of the two liquids take place, and caloric is evolved, contributing to render the gas aeriform, which is thus forced to escape.

This experiment proves that the affinity of sulphuric acid for water is greater than that of muriatic acid.

SECT. II.

EXPERIMENTAL PROOFS

OF THE

PROPERTIES OF MURIATIC ACID GAS.

EXPERIMENT I.

Muriatic acid gas is readily absorbed by water.

FILL a receiver with muriatic acid gas, and introduce into it a little water, the gas will speedily be absorbed, and the fluid exhibit all the properties of muriatic acid.

The absorption may also be shown by disengaging the gas in a retort and dipping the neck into a bason of water, or letting it pass into a receiver moistened with a small quantity of this fluid.

REMARK...Water when charged as highly as possible with this gas forms the ordinary muriatic acid in a liquid state. Ten grains of water are capable of absorbing 10 grains of the gas. The solution thus obtained occupies the space of 13.3 of water nearly. Water heated absorbs it with difficulty. The colder the water the more it absorbs.

Experiment II.

Muriatic acid gas melts ice speedily.

This experiment may be shown by passing the current of muriatic acid gas as it is disengaged, into a vessel filled with ice broken into small pieces. The ice will melt as rapidly as if heat were applied.

Rationale...The rapid liquefaction depends on the vast quantity of caloric which is evolved by the gas when returning from the gazeous to the liquid state, which becomes absorbed by the ice and melts it.

Experiment III.

Muriatic acid gas when brought into contact with air forms white clouds.

If a wide-mouthed bottle be half filled with muriatic acid gas, and atmospheric air be admitted, by removing it from the mercury over which it was charged, the whole vessel will be instantly filled with dense white vapours, and a slight degree of heat will be produced.

Rationale...The vapours are occasioned by the moisture in the air, to which the muriatic acid gas unites in order to become converted into liquid muriatic acid, abandoning at the same time its combined caloric, which becoming free produces the heat.

Remark...The more humid the air the denser the vapours are on presenting muriatic acid gas to it, and for that reason they are never produced on the summits of mountains or other places where the air is very dry.

This production of white vapour is therefore a sure sign of the humidity of the air.

Experiment IV.

Formation of muriate of ammonia by mingling together muriatic acid gas and ammonia.

If muriatic acid gas and ammonia be mingled together in a cylinder over mercury, the mixture becomes instantly heated and a white cloud is formed. The mercury rises and muriate of ammonia will be formed, which crystallizes on the internal surface of the receiver, during the subsiding of the white vapour. If the two gases are very pure and perfectly dry, they completely disappear and the disengagement of caloric is considerable.

Rationale...The production of the muriate of ammonia is owing to the attraction of the bases of the two gases to each other being greater than that of the caloric which kept them in the gazeous state; they therefore abandon the caloric, unite and form a solid combination called muriate of ammonia.

Experiment V.

Muriatic acid gas extinguishes the flame of burning bodies; first enlarging it by the addition of a green or bluish circumambient flame.

If a lighted taper be let down into a receiver filled with muriatic acid gas the flame will be extinguished; but before its extinction it will be enlarged by a green or bluish circumambient flame.

Remark...This curious phenomenon has not yet been satisfactorily explained.

OXIGENATED MURIATIC ACID GAS.

PART XXX.

SECT. I.

WHEN the muriatic acid gas before-mentioned, becomes combined with a certain quantity of oxigen, the result is an expansible gazeous fluid to which chemists have given the name of oxigenated muriatic acid gas.

PROPERTIES OF OXIGENATED MURIATIC ACID GAS.

Oxigenated muriatic acid gas possesses an uncommonly pungent and suffocating odour. It is absolutely and in every respect non-respirable; animals immersed in it die instantly. It is absorbable by water, and forms with it what is called liquid oxigenated muriatic acid. When water is saturated with it, the compound crystallizes at low temperatures. Oxigenated muriatic acid gas is not *invisible*, but has a *yellow-greenish colour*. It is capable of maintaining and exciting combustion in many cases.

Phosphorus, charcoal, red sulphuret of mercury, sulphuret of antimony, bismuth, iron, zinc, copper, gold, arsenic, cobalt, tin, lead, and several other combustible bodies take fire spontaneously when introduced into it. It is heavier than atmospheric air. It weakens and reddens the flame of a taper, but does not extinguish it. It decomposes ammonia. It thickens fat oils. It detonates with hidrogen gas. Nitrous gas immediately produces a cloud of reddish vapour with it. It is likewise decomposed by sulphurated, phosphorated and carbonated hidrogen gases. It is not altered by exposure to light, and passes unaltered through an ignited porcelain tube. It discolours stuffs and totally destroys most of the vegetable colours, rendering them white. It also bleaches yellow wax, &c.

METHODS OF OBTAINING OXIGENATED MURIATIC ACID GAS.

1. Put into a retort one part of powdered black oxid of manganese and three or four of concentrated muriatic acid, connect the retort with the pneumatic trough and receive the gas *over water** in the usual manner. When no more gas is liberated apply the heat of a lamp, and gas will be produced abundantly, which may be kept in bottles with ground glass stoppers.

RATIONALE...The oxid of manganese yields up part of its oxigen to part of the muriatic acid, which becomes converted into oxigenated muriatic acid gas; the oxid of manganese being thus partly de-oxidated is dissolved in the remaining quantity of the muriatic acid, which remains behind in the retort as muriate of manganese.

REMARK...The retort containing the mixture should not be filled above one-third, for the mixture on the application of heat, swells and is otherwise very apt to be forced over into the neck of the retort.

* Though mercury is generally made use of in this process, water answers the purpose very well.

2. Oxigenated muriatic acid gas may likewise be obtained in an indirect manner by decomposing muriate of soda in contact with black oxid of manganese. For that purpose mix eight parts by weight, of muriate of soda with three of powdered oxid of manganese, put the mixture into a tubulated retort, and pour upon it gradually four parts of sulphuric acid, diluted previously with three of water, and which has been suffered to cool after dilution. On applying a gentle heat, gas will be produced as before.

Rationale...In this operation the sulphuric acid acts on the muriate of soda, to the base of which it unites; the muriatic acid formed by this union, attacks the oxid of manganese; one part of it combines with the oxigen and another with the oxid brought nearer to the metallic state, and the result is sulphate of soda and muriate of manganese, which remain in the distilling vessel; and oxigenated muriatic acid, which passes in the state of gas at common temperatures.

Remarks...In preparing this gas great care should be taken that it does not escape into the apartment in any considerable quantity; as it acts violently on the pituitous membrane, occasions a defluxion of the brain, blunts the senses of smell and taste, produces head-ache and proves extremely injurious to health.

Pelletier fell a sacrifice in attempting to breathe it; a consumption was the consequence which proved fatal.

Liquid ammonia is the remedy best calculated to check its effects when accidentally set at liberty in places where it is prepared.

The water which adheres to the inner side of the vessel filled with oxigenated muriatic acid gas, crystallizes in the form of yellow spangles, if the temperature is near the freezing point. If a considerable quantity of gas be thus condensed, care must be taken to keep it at a low temperature, for as soon as the temperature is raised, it expands, and endangers the bursting of the vessel.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF OXIGENATED MURIATIC ACID GAS.

Experiment I.

Oxigenated muriatic acid gas is absorbed by water.

Fill a phial with oxigenated muriatic acid gas and agitate it strongly in contact with water, a rapid absorption will take place, and the water will ascend in the phial. It acquires the colour and odour of the gas, and the property of discharging vegetable colours.

Experiment II.

Oxigenated muriatic acid gas destroys vegetable colours and renders them white.

Fill a vessel with oxigenated muriatic acid gas, and introduce into it a sprig of mint, a rose, &c. Its colour will soon be destroyed and the gas diminished.

All flowers of variegated colours and green leaves of plants are in time rendered white by it; and no alcali is capable of restoring their colour.

Rationale...This effect can be ascribed only to the absorption of oxigen. This gas which contains it in excess, gives up a part of it, which vegetable substances absorb with avidity; and by this absorption lose their colour: the oxigenated muriatic acid gas then becomes converted into common muriatic acid gas.

Remark...It is this property which induced a new method of bleaching which has proved completely successful. The advantages which result from this application of the oxigenated muriatic acid, either in the gazeous or the liquid state have accelerated the process of whitening thread, cotton, linen, wax, &c. to a really surprising degree, in every season of the year, and can be justly appreciated by commercial people only, who experience its beneficial effects from the quick circulation of their capitals.

Experiment III.

Bleaching of linen, calico, &c. by oxigenated muriatic acid gas.

Suspend some unbleached calico or linen moistened with water, in a jar filled with oxigenated muriatic acid gas. The natural colour of the stuff will soon begin to fade, and at last totally disappear.

If different coloured patterns of calico or printed cotton be immersed for a few minutes into the gas, their colours will soon be destroyed, except those which are yellow.

Experiment IV.

Oxigenated muriatic acid gas supports flame.

Though oxigenated muriatic acid gas is exceedingly noxious to life, it does not extinguish combustion.

If a burning taper affixed to a wire be immersed in it, the taper burns of a red colour and more vividly than in atmospheric air, a great quantity of smoke is emitted at the same time.

Experiment V.

Spontaneous accension of metals in oxigenated muriatic acid gas.

Fill a tall receiver furnished with a ground stopper, with pure oxigenated muriatic acid gas, over water, and let fall into it, copper beaten out into a thin leaf (Dutch gold). The copper leaf before it reaches the bottom of the receiver will burn with a pale green light.

Gold leaf may be burnt in a similar manner.

Fine copper wire when heated to redness, also takes fire when introduced into the gas in that state.

Other metals may be inflamed in oxigenated muriatic acid gas in the following manner:

Experiment VI.

Fill a tall bell-glass, furnished with a stopper at the top, with oxigenated muriatic acid gas, and throw into it in small quantities either some antimony or arsenic reduced to a fine powder. The metal introduced will instantly inflame and appear like a shower of fire.

Tin, cobalt, bismuth, nickel, copper, &c. reduced to a fine powder, may be inflamed in a similar manner.

Rationale...The metals presented to the oxigenated muriatic acid gas rapidly subtract its oxigen and become converted into oxids; the combined light and heat of both the gas and the metal are disengaged and appear under the form of fire; and the oxigenated muriatic acid gas returns to the state of simple muriatic acid gas.

Remark...To succeed well in making these experiments, it is necessary that the metal should be reduced to a fine powder, and employed in the proportion of a grain to two or three cubic inches of gas. The gas made use of should be perfectly pure and fresh prepared. If the gas be warmed a little the pheno-

mena never fail. Iron, lead, and zinc are more difficult to inflame than any of the former; it frequently happens that they remain unaltered at the bottom of the vessel, for some time, but on a sudden the accension takes place. Nickel, arsenic, and bismuth, are the metals which are most readily inflamed, and which burn most brilliantly.

Experiment VII.

Spontaneous accension of phosphorus in oxigenated muriatic acid gas.

Put some minutely divided phosphorus, dried on blotting-paper, into a copper ladle, and introduce it into a jar filled with oxigenated muriatic acid gas, the phosphorus will instantly kindle and burn with a greenish white light.

Rationale...The phosphorus unites with the oxigen of the oxigenated muriatic acid gas, and becomes converted into phosphoric acid; the oxigenated muriatic acid gas by thus losing its oxigen, returns to the state of muriatic acid gas.

Experiment VIII.

Spontaneous accension of sulphur in oxigenated muriatic acid gas.

If a piece of sulphur be presented to oxigenated muriatic acid gas no action ensues; but if we *melt* a little sulphur in a ladle, and then introduce it, in a state of perfect liquidity, into a jar filled with this gas, the sulphur will take fire and burn rapidly.

Rationale...The explanation of this experiment is analogous to the former; the sulphur decomposes the oxigenated muriatic acid gas, and becomes converted into sulphuric acid: but before that effect can take place, the attraction of cohesion of the

particles of sulphur must be demolished; that is to say, the sulphur must be rendered fluid, which was not necessary with phosphorus.

Experiment IX.

Spontaneous accension of metallic sulphurets by oxigenated muriatic acid gas.

Sulphuret of antimony reduced to a fine powder, and introduced into the gas, in the same manner as was directed for the accension of the metals, will also take fire.

A similar effect is produced by this gas on sulphuret of mercury, iron, &c.

A variety of other combustible substances may also be inflamed by presenting them to oxigenated muriatic acid gas, in its nascent state, as was first shown by Professor Davy.*

Experiment X.

Accension of ether, alcohol, or oil of turpentine by oxigenated muriatic acid gas in its nascent state.

Put into a wine-glass one part of oxigenated muriate of potash perfectly dry, and pour on it two of colourless sulphuric acid of commerce, a violent action will take place, and oxigenated muriatic acid gas be evolved. If, during the extrication of this gas, one part of sulphuric ether, alcohol, or oil of turpentine, be suffered to fall into the gas, an accension takes place, accompanied with a crackling noise.

Remark...In this manner not only all the inflammable fluid bodies, but likewise most of the solids, such as camphor, resin, tallow, pitch, elastic gum, &c. may easily be inflamed.

* Nicholson's Journal, April, 1802, p. 296.

Experiment XI.

Accension of expressed oils at the surface of water, by oxigenated muriatic acid gas.

Put into a glass cylinder one part of oxigenated muriate of potash; add to it three or four of water, and half a part of oil of olives, or of linseed. On adding to it four or five parts of concentrated sulphuric acid, a violent action takes place, much charcoal becomes deposited, and a multitude of ignited sparks pass through the black fluid, exhibiting a beautiful phenomenon. On adding an additional quantity of oxigenated muriate of potash and sulphuric acid, the whole mass takes fire and burns with a dense yellow flame.

Experiment XII.

Accension of phosphorus in oxigenated muriatic acid gas, under the surface of water.

Let fall into a wine-glass, or rather into a long cylinder, two-thirds filled with water, one part of phosphorus, and two of oxigenated muriate of potash. On adding to this mixture three or four parts of sulphuric or nitric acid, the phosphorus takes fire, and burns vividly *under the surface* of the fluid: on agitating the mixture, streams of ignited sparks pass through the water rapidly.

Remark...This and the two preceding experiments require caution. The operator ought to be distant during the affusion of the acids, or the addition of the combustible body, which are sometimes thrown out of the vessel to a considerable distance.

Experiment XIII.

Nitrous gas and oxigenated muriatic acid gas, readily unite and produce nitro-muriatic acid.

This may be shown by sending up into a receiver filled with oxigenated muriatic acid gas, bubbles of nitrous gas; the mixture

becomes warm, reddish fumes appear, and nitro-muriatic acid is produced.

RATIONALE...The nitrous gas takes part of the oxigen from the oxigenated muriatic acid gas, and becomes converted into nitrous acid; it then unites to the oxigenated muriatic acid gas, and forms with it nitro-muriatic acid.

EXPERIMENT XIV.

Decomposition of oxigenated muriatic acid gas by ammonia.

If fresh prepared oxigenated muriatic acid gas and ammonia be mingled together over mercury, a rapid detonation takes place accompanied with a white flame, and the receiver becomes filled with dense white vapours.

RATIONALE...The oxigen of the oxigenated muriatic acid gas unites to the hidrogen of the ammonia and produces water, whilst the nitrogen of the ammonia is liberated, and the oxigenated muriatic acid gas becomes converted into simple muriatic acid.

REMARK...This experiment requires caution. The cylinder in which the gases are mingled should be very strong, and the gases should be mixt in small quantity. The experiment succeeds exceedingly well if about two cubic inches of ammonia are sent up into a jar holding at least eighteen cubic inches of oxigenated muriatic acid gas.

FLUORIC ACID GAS.

PART XXXI.

SECT. I.

THE composition, or the radical of fluoric acid gas is equally unknown; for no experiments have yet been made by which it can be exhibited. It is merely from general inference, that we may conjecture it to consist of a simple acidifiable basis united to oxigen.

PROPERTIES OF FLUORIC ACID GAS.

The most remarkable property of this gas, is its power of dissolving silex, and keeping it suspended in the gazeous state; it therefore dissolves glass, crystals and various precious stones. It is heavier than atmospheric air. It does not maintain combustion, nor can animals breathe it. It is absorbed by water and forms with it liquid fluoric acid. It has a penetrating odour, approaching nearly to that of muriatic acid gas. It corrodes animal and vegetable matters. Light has no effect upon it. It emits white fumes in contact with moist atmospheric air. It is very sour and therefore reddens blue vegetable colours. It precipitates lime

water. With ammonia it unites and forms a concrete body. It has no action upon platina, gold, silver, mercury, tin, lead, antimony, cobalt, nickel, or bismuth; but it attacks iron, arsenic, and manganese.

METHODS OF OBTAINING FLUORIC ACID GAS.

1. Fluoric acid gas may be obtained by decomposing fluate of lime (Derbyshire spar) by means of sulphuric acid.

For that purpose, put one part of powdered fluate of lime into a leaden or tin retort, and pour over it two or three parts of concentrated sulphuric acid. A violent action takes place instantly and fluoric acid gas is extricated which must be collected over mercury, either in a leaden or tin vessel, or in a glass receiver covered within with a thick coat of varnish or wax. When no more gas is produced spontaneously, the action of the acid must be assisted by a gentle heat.

RATIONALE...Fluate of lime consits of fluoric acid united to lime; on adding sulphuric acid a decomposition takes place. The sulphuric acid having a greater attraction for the lime than the fluoric acid, unites to it and forms sulphate of lime, disengaging at the same time the fluoric acid, which takes the gazeous state at the instant of its extrication and appears under the form of fluoric acid gas.

2. Fluoric acid gas may likewise be obtained from liquid fluoric acid, (water impregnated with fluoric acid gas) by heat.

SECT. II.

EXPERIMENTAL PROOFS

OF

THE PROPERTIES OF FLUORIC ACID GAS.

Experiment I.

Fluoric acid gas is absorbable by water.

INTRODUCE into a receiver coated within with wax, and filled with fluoric acid gas, a little water, and agitate it; heat will be produced, the gas will vanish, and the mercury rise into the receiver.

If the water be examined, it will be found to possess all the properties of fluoric acid, it will corrode glass, quartz, and other siliceous substances. If it be exposed to heat, part of the absorbed gas becomes extricated again, but the last portion adheres to it so strongly that the water and the rest of the acid are volatilized if the heat be increased.

Experiment II.

Fluoric acid gas extinguishes light and kills animals.

If a lighted taper be plunged into a vessel filled with this gas it will instantly be extinguished. An animal thrown into it soon dies.

Experiment III.

Fluoric acid gas dissolves silex, glass, quartz, &c.

This may be proved by disengaging fluoric acid gas from a leaden or tin retort, and collecting the gas in a common dry glass receiver. The gas as it enters the vessel acts upon the silex of the glass, and the receiver becomes opaque by reason of its internal surface being corroded.

Remark....This property of dissolving silex has given the idea of etching on glass either by means of the fluoric acid gas, or liquid fluoric acid.

Experiment IV.

To etch upon glass by means of fluoric acid gas.

Take a pane of glass, clean it well, and cover it over either with a thin coat of bees wax, isinglass dissolved in water, or engravers varnish. When it is dry trace upon it, by means of a graver or any other sharp pointed instrument, any subject you chuse; having done this take some powdered fluate of lime, put it into a leaden bason, and pour over it a sufficient quantity of sulphuric acid, stirring it with a stick or slip of glass; then hold the pane of glass close over it in order that the gas which is disengaged may act upon the glass, which will soon become corroded and appear like engraving, when the varnish or coating is removed. In order to assist the action of the sulphuric acid, the bason containing the mixture may be held over a lamp, or gentle coal-fire.

This property of fluoric acid gas may be advantageously employed for engraving labels on glass bottles intended to contain acids; for graduating glass tubes, thermometers, &c. for ornamenting glass vessels; for removing injured enamels, &c.

REMARK...The art of etching on glass, which is generally considered as of modern date, does not entirely belong to our cotemporaries; even to assert that the ancients were altogether unacquainted with it, would be unjust. It seems rather that this art belongs to the discoveries which were made in those times, in which men were little inclined to transmit an account of their inventions to posterity, and thus may have been forgotten or lost. Scheele discovered the fluoric acid and re-invented the art of etching on glass, in 1771. But that it was practised a century before, by a German, whose name was *Swanhard*, we have endeavoured to prove in *Nicholson's Journal for April*, 1800.

Had this person been able to pursue properly the discovery which either accident or ingenuity presented to him, he might have enriched us with an art which acquired great reputation to Scheele a hundred years after.

EXPERIMENT V.

Fluoric acid gas not only dissolves, but also volatilizes siliccous earth.

This may be shown by decomposing fluate of lime in a glass retort, and receiving the gas in a vessel filled with water, and resting upon mercury. Each bubble of the gas which passes through the mercury into the water becomes immediately enveloped in silex, and leaves, as it ascends to the surface of the water, traces in the form of tubes, which frequently decrease to a point upwards, because the bubble diminishes in proportion as the water dissolves it, and the silex is carried off.

RATIONALE...The gas when disengaged in the glass retort dissolves part of the silex of that vessel, which it keeps in an aeriform state. On coming into contact with the water it abandons its caloric and becomes converted into liquid fluoric acid, depositing at the same time the siliceous earth.

Remark...If substances capable of retaining moisture be exposed to fluoric acid gas, holding silex in solution, the water they contain will absorb the acid and the siliceous earth will be precipitated upon them. In this manner lizards, frogs, moist fruits, bits of sponge, &c. may be encrusted with a coat of silex. Objects thus covered with a close and very hard siliceous crust greatly resemble petrifactions, and may be preserved for a long time.

PHOSPHORATED CARBONATED HIDROGEN GAS.

In Van Mon's Journal de Chimie et de Phisique, p. 213, is published an account of a new species of gas discovered by Professor Tromsdorf, which is composed of hidrogen, carbon, and phosphorus. It was obtained by this gentleman during the de-oxidation of phosphoric acid by charcoal, in the common process of distilling phosphorus. Its weight is nearly equal to that of atmospheric air. It is not absorbed by water, oxigen has no effect upon it at common temperatures, but explodes with it by the electric spark. It has no action on metallic oxids, but decomposes the solutions of gold, silver and mercury. The products after its detonation with oxigen are carbonic acid gas, phosphoric acid and water. From these results Professor Tromsdorf proposes to call it phosphorated carbonated hidrogen gas.

No further account of this gas having as yet reached us, we are not enabled to enter more fully into the subject, but as the learned Professor has promised to investigate its properties, and publish the results, we may expect to be acquainted with it shortly.

THEORIES

OF

COMBUSTION.

PART XXXII.

AMONG the various operations of chemistry none acts a more conspicuous part than combustion; and in proportion to its utility in the science, the necessity of thoroughly investigating its nature and mode of action becomes more obvious to the philosophical chemist. It was a conviction of the importance of this enquiry which induced Lavoisier to examine with accuracy the labours of his predecessors, and by this pursuit he was enabled to form a theory of this process, which though not absolutely free from error, was such as well entitled its author to the distinguished rank he holds among philosophers. And as this theory, though capable of improvement, will probably serve for a foundation to every discovery which may be made in this branch of the science, we shall state it here with a view that our readers may be enabled to appreciate its value.

SECT. I.

LAVOISIER's THEORY OF COMBUSTION.

LAVOISIER's theory of combustion is founded upon the absorption of oxigen by a combustible body.

We have seen that bodies cannot burn in a limited quantity of air beyond a certain period; (page 222) that a real analysis of this fluid is effected; and that combustion is not confined to the decomposition of the atmosphere only, by absorbing one of its principles; but that it also decomposes oxigen gas, by absorbing, fixing, and rendering more or less solid, in the combustible body, the oxigen or basis of the oxigen gas, and disengaging its solvent, the caloric, under the appearance of heat and flame. *See page* 188.

Taking this for granted, it follows that combustion is only the play of affinity between oxigen, the matter of heat, and a combustible body.

When an *incombustible* body, a brick for instance, is heated, it undergoes no change except an augmentation of bulk and temperature, and when left to itself it soon regains its former state. But when a *combustible* body is heated to a certain degree in the open air it begins to become on a sudden intensely hot, and at last emits a copious stream of caloric and light to the surrounding bodies. During this emission the burning body gradually wastes away. It either disappears entirely, or its physical pro-

perties become totally altered. The principal change it suffers is that of being no longer capable of combustion.

If either of these phenomena, namely, the emission of heat and light, and the waste of substance, be wanting, we do not say that a body is undergoing combustion, or that it is burning.

It follows therefore that every theory of combustion ought to explain the following facts:

1. Why a burning body is consumed, and its individuality destroyed.

2. Why, during the progress of this alteration, heat and light are emitted.

For the elucidation of these objects Lavoisier's theory has laid down the following laws:

1. Combustion cannot take place without the presence of oxigen, and is more rapid in proportion to the quantity of this agent in contact with the inflamed body.

2. In every act of combustion the oxigen present is consumed.

3. The weight of the products of every body after combustion corresponds with the weight of the body before combustion *plus* that of the oxigen consumed.

4. The oxigen absorbed by the combustible body may be recovered from the compound formed, and the weight regained will be equal to the weight which disappeared during the combustion.

5. In every instance of combustion light and heat or fire, are liberated.

6. In a limited quantity of air, only a certain quantity of the combustible body can be burnt.

7. The air, wherein a body has been burnt, is rendered unfit for maintaining combustion, or supporting animal life.

Though every case of combustion requires that light and heat should be evolved, yet this process proceeds very differently in different circumstances, hence the terms *ignition*, or glowing heat; *inflammation* or accension; and *detonation* or explosion.

IGNITION

Takes place when the combustible body is not in an aeriform state.

Charcoal, pyrophorus, &c. furnish instances of this kind.

It seems as if the phenomenon of glowing was peculiar to those bodies which require a considerable quantity of oxigen to become converted into the gazeous state.

The disengagement of caloric and light is rendered more evident to the senses in the act of

INFLAMMATION,

Or accension. Here the combustible substances are more easily converted into an elastic or aeriform state. Flame therefore consists of the inflammable matter in the act of combustion in the gazeous state. When all circumstances are favorable to the complete combustion of the products, the flame is perfect; if this is not the case, part of the combustible body, capable of being converted into the gazeous state, passes through the luminous flame unburnt, and exhibits the appearance of smoke. Soot therefore always indicates an imperfect combustion. Hence a common lamp smokes, an Argand's lamp yields no smoke.

This degree of combustion is very accurately exemplified in the

FLAME OF CANDLES.

When a candle is first lighted, which must be done by the application of actual flame, a degree of heat is given to the wick sufficient to destroy the affinity of its constituent parts; part of the tallow is instantly melted, volatilized, and decomposed; its hidrogen takes fire and the candle burns. As this is destroyed by combustion another portion melts, rises and supplies its place, and undergoes a like decomposition In this way combustion is

maintained. The tallow is liquefied as it comes into the vicinity of the flame, and is by the capillary attraction of the wick drawn up to supply the place of what is decomposed; the unmelted tallow by this means forms a kind of cup.

The congeries of capillary tubes which form the wick is black, because the charcoal of the cotton becomes predominant, the circum-ambient air is defended by the flame from oxidating it, it therefore remains for a considerable time in its natural state; but when the wick by the continual consumption of tallow becomes too long to support itself in a perpendicular position, its upper extremity projects nearly out of the cone of the flame, and there forms a support for an accumulation of soot, which is produced by the imperfect combustion. A candle in this situation affords scarcely one-tenth of the light it can give, and tallow candles on this account require continual snuffing.

But if the candle be made of wax, the wick does not long occupy its place in the middle of the flame; its thinness makes it bend on one side when its length is too great for its vertical position; its extremity comes then into contact with the air, and is completely burnt or decomposed, except so much of it as is defended by the continual afflux of the melted wax. This small wick therefore performs the office of snuffing itself. The difficult fusibility of wax enables us to use a thinner wick for it, than can be used for tallow which is more fusible. But wax being a substance which contains much more oxigen than tallow or oil, the light it affords is not so luminous.

DETONATION

Is an instantaneous combustion accompanied with a loud report; it takes place in general when the compound resulting from the union of two or more bodies occupies less space than the substances did before their union, a vacuum is therefore formed, and the surrounding air rushing in from all sides to fill it up is the cause of the report.

Gun-powder, fulminating gold, silver, and mercury; oxigenated muriate of potash; and various other explosive compounds are capable of producing very loud detonations, as we shall see hereafter.

Let us now consider the disengagement of light and caloric.

By the older chemists it was universally supposed that the light and heat emitted during combustion proceeded from the inflammable body; and this opinion would indeed appear unquestionable while the composition of the atmosphere was imperfectly known. The burning body appeared luminous and felt hot, and no other agent was supposed to be concerned; the conclusion that the light and heat were evolved from the burning substance was therefore unavoidable.

But when the nature of the atmosphere was ascertained; and when it became evident that part of the air was absorbed during combustion; the former conclusion fell to the ground. For when two bodies exert a mutual action on each other, it becomes *a priori* equally probable that the products may be derived from either of them, consequently the light and heat evolved might proceed either from the one or the other. Whether they proceed from the atmosphere, or from the combustible body, they must be separated at the part where the combination takes place; that is upon the surface of the burning body itself, and consequently it appeared luminous and heated, while the air being invisible escaped observation.

When the laws of heat became known, at least when it was ascertained that bodies in the aeriform state contain at the same temperature, and in equal quantities, either of mass or bulk, unequal quantities of heat, (see page 98) the conclusion became probable, that the caloric evolved in combustion proceeded rather from the oxigen gas of the atmosphere, than from the combustible body; since the former contains a much larger quantity than the latter. The caloric evolved was therefore supposed to be derived from the *condensation* of the oxigen gas in the new combination into which it entered.

Though *approaching* to the truth, this explanation is not strictly true. It is not merely from the oxigen gas being *condensed* that the caloric is evolved, because in many cases of combustion, the product still exists in the gazeous state, (see p. 190) and in others the quantity of caloric evolved bears no proportion to the degree of condensation. Philosophers ascribed this to a change of capacity, for in different bodies the difference in the proportion of the capacities before and after combustion is by no means uniform, and hence the difference in the quantities of caloric extricated in various cases of combustion.

This being premised it remains to explain the origin of the light emitted during combustion; for although we take it for granted that the caloric is evolved from the oxigen gas, we cannot infer that the light has the same origin.

It is very probable that light is a constituent part of inflammable bodies; for it is frequently evolved in combinations when the oxigen is merely *transferred* from one inflammable substance to another. In those cases it must proceed from the inflammable body. The accension of oils by the affusion of acids (page 19) the combustion of metals with sulphur (page 149) furnish intances of the kind.

It seems therefore probable that the light is derived from the inflammable substance; and that the oxigen combining with the bases of these substances disengages the light. It is *possible* that part of it may also be derived from the oxigen gas, but it is evidently unnecessary to *suppose so*.

It may be concluded then that light enters into the composition of all combustible bodies, but as we are unable to separate the light so as to obtain these bodies pure we treat of them as simple bodies.

According to this theory the combustion of phosphorus in oxigen gas (page 188) is therefore the effect of a double affinity. The basis of the oxigen gas unites with the phosphorus to form phosphoric acid; and the light disengaged from the phosphorus

together with part of that of the oxigen gas, produces the vivid flame.

The quantity of light emitted by different bodies is supposed to depend on the quantity contained in them, and on the proportion in which it is united to caloric.

Such is the theory of combustion of Lavoisier modified by Gren, Leonhardi, Richter, and publicly taught in this capital by Dr. Crichton.

Other teachers consider this theory as a modification of the old doctrine of Stahl, saying that light is substituted for phlogiston, but this is a mere verbal conceit which probably only originates from the prejudice which the partizans harbour in favour of the original theory of Lavoisier.

SECT. II.

THOMSON's

THEORY OF COMBUSTION.

THOUGH the preceding theory of combustion is simple and beautiful, it appears from what we are now going to state, to be by no means satisfactory.

It has misled chemists by confining the term combustion to the act of oxigenation, and considering that all bodies, during their combustion, combine with oxigen, without at the same time recollecting, that this latter effect may take place without any of the phenomena usually attendant on combustion; and that, though certainly all combustion pre-supposes the combination of oxigen with a base, yet this combination may be, and repeatedly is effected where no combustion can possibly take place. Nothing can be more evident than the difference which in numberless instances prevails between the act of oxigenation in bodies, and that of combustion, in as much as neither the phenomena attending on, nor the results arising from them are the same. That a distinction therefore should be made between these processes is obvious; and it is on this account that Dr. Thomson has offered a theory which considers this subject in a new point of view, and which bids fair to enable us to estimate the phenomena of combustion much better than has hitherto been done.

According to Dr. Thomson's* theory, all the bodies concerned in combustion are either, 1. *Combustibles*...2. *Supporters of combustion*...3. *Incombustibles*.

I. COMBUSTIBLE BODIES are those substances which are said in common language to *burn*. During the combustion they appear to emit light and heat, and at the same time gradually waste away. When this change has reached its *maximum*, the process of combustion is at an end.

The class of combustibles is very numerous; but all the bodies belonging to it may be sub-divided into three sets, namely;

1. Simple combustibles,
2. Compound combustibles,
3. Combustible oxids.

Simple Combustibles.

1. SULPHUR,
2. PHOSPHORUS,
3. DIAMOND,
4. HIDROGEN GAS,
5. ALL THE METALS.

Compound Combustibles.

The *compound combustibles* consist of compounds, formed by the simple combustibles uniting together two and two, and are of course much more numerous than the simple combustibles. They may be arranged under the five following heads:

1. SULPHURETS,
2. PHOSPHURETS,
3. CARBURETS,
4. ALLOYS,
5. SULPHURATED, PHOSPHORATED, AND CARBONATED HIDROGEN.

The *combustible oxids* are either simple, having a single base, or compound, having more than one base. All the simple combustible oxids, are by combustion converted into acids.

* Nicholson's Journal, 1802, No. V. p: 10.

The compound combustible oxids are by far the most numerous.

II. The SUPPORTERS of COMBUSTION are bodies which are not of themselves, strictly speaking, capable of undergoing combustion, but which are absolutely necessary for the process; for no combustible body can burn unless some one or other of them be present. Whenever they are excluded, combustion ceases. All the supporters of combustion known at present are the following six:

1. OXIGEN GAS, 2. AIR,
3. GAZEOUS OXID OF NITROGEN,
4. NITROUS GAS, 5. NITRIC ACID,
6. OXIGENATED MURIATIC ACID.

There are indeed certain substances besides these, which possess nearly the same properties; these shall be afterwards enumerated under the title of *partial supporters*.

They all contain one common principle, namely *oxigen*.

III. The INCOMBUSTIBLE BODIES are neither capable of undergoing combustion themselves, nor of supporting the combustion of those bodies that are; they are therefore not immediately connected with combustion. At present we are acquainted with about 13 incombustible bodies, not reckoning the compounds which they are capable of forming with each other. These are,

1. NITROGEN GAS, 2 THE ALCALIES,
3 THE EARTHS.

Some of the alcalies and earths possess certain properties in common with combustibles, and are capable of exhibiting phenomena somewhat analagous to combustion; which will be described afterwards under the title of *semi-combustion*.

3. In every case of combustion there must therefore be present a *combustible* body and a *supporter* of combustion. During combustion the combustible always unites with the oxigen of the supporter. *It is this combination which occasions the apparent waste and alteration of the combustible.* The new compound thus formed is a *product of combustion.* Every product of combustion is either, 1. *water,* or 2. *an acid,* or 3. *a metallic oxid.* It is true indeed, that other bodies sometimes make their appearance during combustion, but these will be found upon examination not to be products, nor to have undergone combustion.

Thus one of the two characteristic marks which distinguish combustion, namely, the apparent *waste and alteration of the combustible body,* has been fully explained. For the explanation of it we are indebted to Lavoisier, as stated before.

But though the combination of the combustible with oxigen be a constant part of combustion, yet the facility with which combustibles burn is not proportional to their apparent affinity for oxigen.

Phosphorus, for instance, burns more readily than charcoal; yet charcoal is capable of abstracting oxigen from phosphorus, and of course has a greater affinity for it...(See page 156). The combustible oxids take fire more readily than some of the simple combustibles; thus charcoal burns more easily than diamond, (page 173): alcohol, ether, and oils, are exceedingly combustible, whereas all the metals require very high temperatures when ths supporter is air.

This greater combustibility of combustible oxids is probably owing to the weaker affinity by which their particles are united. Hence they are more easily separated than homogeneous particles, and of course combine more readily with oxigen; those simple combustibles which melt easily, or which are in the state of elastic fluids, are also very combustible, because the cohesion between their particles is easily overcome.

It is owing to the same inferiority in the cohesion of heterogeneous particles, that some of the compound supporters occasion combustion in circumstances when the combustibles would not be acted on by simple supporters.

Thus phosphorus burns in air at the common temperature; (p. 158) but it does not burn in oxigen gas, unless its temperature be raised* (p. 188). In oxigenated muriatic acid gas, phosphorus burns rapidly at the common temperature of the air, and so do several of the metals; though they cannot be made to burn in air except at a very high temperature. Thus also oils burn rapidly when mixed with nitrous acid (page 19). Nitrous gas and the gazeous oxid of nitrogen constitute exceptions to this rule.

4. None of the *products* of combustion are combustible according to the definition of combustion here given. This want of combustibility is not owing to their being saturated with oxigen; for several of them are capable of combining with an *additional dose* of it. But during this combination no caloric or light is ever emitted; and the compound formed differs essentially from a *product* of combustion; for by this additional dose of oxigen the *product* is converted into a *supporter*. *Hence we see that combustion ought not to be confounded with the combination of a body with oxigen*, as was done formerly.

Combustion indeed cannot take place without the combination of oxigen; but oxigen may combine with bodies in different proportions without the phenomena of combustion; and the *product obtained* is capable of becoming converted into a *supporter* of *combustion*, for instance: If lead be melted, and kept so for some time, it becomes covered with a white pellicle, or white *oxid of lead*, a product consisting of oxigen and lead; but if this white oxid is suffered to be heated longer, it absorbs an additional quantity of oxigen, and becomes converted into a yellow

* In the gazeous oxid of nitrogen it requires a still higher temperature.

powder, called yellow *oxid of lead*. If this yellow oxid be again exposed to heat, it absorbs still more oxigen, and becomes converted into *red oxid of lead*. All these oxids are therefore *supporters*. When the *supporters*, thus formed by the combination of oxigen with *products*, are made to support combustion, they do not lose all their oxigen but only the additional dose which constituted them supporters. Of course they are again reduced to their original state of products of combustion. Hence it follows, that they owe their properties as supporters, not to the *whole* of the oxigen which they contain, but to the *additional dose* which constituted them supporters. We may therefore call them *partial supporters*, indicating by the term, that part only of their oxigen is capable of supporting combustion and not the whole.*

All the partial supporters with which we are acquainted, contain a metallic basis; for metallic oxids are the only products at present known capable of combining with an additional dose of oxigen. It is a circumstance highly deserving attention that when metals are capable of combining with several doses of oxigen, the product or oxid formed by combustion is seldom or never that which contains a *maximum* of oxigen.

Thus it is evident that several of the products of combustion are capable of combining with oxigen. *The incombustibility of products, therefore, is not owing to their want of affinity for oxigen*, but to some other cause.

5. No *product* of combustion is capable of *supporting* combustion. This is not occasioned by any want of affinity for combustible bodies; for several of them are capable of combining with an additional dose of their basis. But by this combination they *lose* their properties as products, and are converted into *combus-*

* Dr. Thomfon suppofes that it is very possible that both nitrogen and muriatic acid may be products of combustion; and in that case both the compound and partial fupporters would agree with each other in every refpect. In the prefent state of our knowledge, however, it is neceffary to distinguish them.

tibles. The process therefore differs essentially from combustion. Thus sulphuric acid, a *product* of combustion, by combining with an additional dose of sulphur or its oxid, is converted into *sulphureous acid,* a substance which, from several of its properties, the doctor concludes to be combustible. Thus also phosphoric acid, a product of combustion, is capable of combining with phosphorated hidrogen, and of forming *phosphorous* acid a combustible body. When this last acid is heated in contact with a supporter, it undergoes combustion; but it is only the additional dose of the combustible which burns, and the whole is converted into phosphoric acid. Hence we see that it is not the whole basis of these compounds which is combustible, but merely the additional dose. The compounds, therefore, formed by the union of a product and combustible, may be termed *partial combustibles;* indicating by the name, that a part only of the base is capable of undergoing combustion. Since the products of combustion are capable of combining with oxigen, but never exhibit the phenomena of combustion except when they are in the state of partial combustibles, combustible bodies must contain a substance which they lose in burning, and to which they owe their combustibility; for after they have lost it, they unite to oxigen *without* exhibiting the phenomena of combustion.

Though the products of combustion are not capable of supporting combustion, they not unfrequently part with their oxigen just as supporters do, give it out to combustibles, and convert them into products; but during this process no heat nor light is ever evolved. Water, for instance, gives out its oxigen to iron, and converts it into *black oxid,* a product; and sulphuric acid gives out its oxigen to phosphorus, and converts it into phosphoric acid. Thus we see that the oxigen of products is capable of converting combustibles into products, just as the oxigen of supporters; but during the combination of the last only, are heat and light emitted. The oxigen of supporters then contains something which the oxigen of products wants.

6. Whenever the whole of the oxigen is abstracted from products, the combustibility of their base is restored as completely as before combustion; but no substance is capable of abstracting the whole of the oxigen, except a *combustible*, or a *partial combustible*. Water, for instance, is a product of combustion, whose base is hidrogen. To restore the combustibility of the hidrogen, we have only to mix water with iron or zinc filings and an acid; the metal is oxidated, and the hidrogen gas is evolved as combustible as ever. But no substance, except a combustible, is capable of separating hidrogen gas from water by combining with its oxigen. Thus we see that combustibles are capable of restoring the combustibility of the bases of products, but they themselves lose their combustibility by the process, and are converted into products. Combustibility, therefore, may be thrown at pleasure from one body to another.

From these facts it is obvious, that the products of combustion may be formed without combustion; but in these cases a new combustible is always evolved. The process is merely an interchange of combustibility; for the combustible is converted into a product only by means of a product. Both the oxigen and the base of the product having undergone combustion, have lost something which is essential to combustion. The process is merely a double decomposition. The product yields its oxigen to the combustible, while at the same time the combustible gives out something to the base of the product; the combustibility of that base then is restored by the loss of its oxigen, and by the restoration of something which it receives from the other combustible thus converted into a product.

There is indeed another method of forming the products of combustion without actual combustion in certain cases; but the phenomena are much more complicated. This method is to expose them to the action of some of the supporters dissolved in water; especially nitric acid. Thus most of the metallic oxids may be formed without combustion by the action of that acid on the metals. But in that case a new supporter is always evolved,

namely, nitrous gas; ammonia, a new combustible, is also usually formed; and not unfrequently the *product* is converted into a *partial supporter*.

7. No *supporter* can be produced by combustion, or by any equivalent process. As all the supporters, except oxigen gas, consist of oxigen combined with a base, it follows as a consequence, that oxigen may combine with a base without losing that ingredient, which occasions combustion. The act of combination of oxigen with a base, therefore, is by no means the same with combustion, If we take a view of the different supporters, we shall find that all of them which can be obtained artificially, are procured either from other supporters, or by the agency of electricity.

I. OXIGEN GAS may be procured from nitric acid and oxigenated muriatic acid, (p. 185...6) two supporters; and from several of the partial supporters, as the black oxid of manganese the red oxids of lead and of mercury (page 187). The action of heat is always necessary; but the process is very different from combustion.

II. AIR, as far as is known at present, cannot be formed artificially. The gas indeed which comes over during part of the usual distillation of nitrate of potash and sulphuric acid to obtain nitrous acid, resembles air very closely. But it is obtained from a supporter.

III. The GAZEOUS OXID OF NITROGEN has hitherto been only procured from nitrous gas and nitric acid (nitrate of ammonia), both of which are supporters.

IV. NITROUS GAS can only be procured by the decomposition of nitric acid, a supporter.

V. OXIGENATED MURIATIC ACID can be formed by combining muriatic acid with the oxigen of the black oxid of manganese, the red oxids of lead, iron, mercury, (page 335) &c. all of which are partial supporters.

VI. NITRIC ACID is formed spontaneously upon the surface of the earth by processes with which we are but imperfectly ac-

quainted; but which certainly have no resemblance to combustion. Its oxigen is probably furnished by the *air*, which is a supporter: at least, it has been observed, that nitrogen and oxigen at high temperatures are capable of forming nitric acid, (page 211).

This formation of nitric acid by means of electricity, has been considered as a combustion, but for what reason it is not easy to say: the substance acted upon is not a combustible with a supporter, but a supporter alone. Electricity is so far from being equivalent to combustion, that it sometimes acts in a manner diametrically opposite; *unburning*, if we may use the expression, a substance which has already undergone combustion, and converting a *product* into a *combustible* and a *supporter*. Thus it decomposes water, and converts it into oxigen and hidrogen gas; therefore it must be capable of supplying the substances which the oxigen and combustible lose when they combine by combustion, and form a product.*

8. Several of the supporters and partial supporters are capable of combining with combustibles, without undergoing decomposition, or exhibiting the phenomena of combustion. In this manner the yellow oxid of gold and the white oxid of silver combine with ammonia; the red oxid of mercury with oxalic acid; and oxigenated muriatic acid with ammonia. Thus also nitrate of potash and oxigenated muriate of potash may be combined, or at least intimately mixed with several combustible bodies, as in gunpowder, fulminating powder, &c. In all these compounds the oxigen of the supporter and the combustible retain the ingredients which render them susceptible of combustion; hence the compound is still combustible: And in consequence of the intimate combination of the component parts, the least alteration is apt to destroy the equilibrium which subsists between them; the consequence is, combustion and the formation of a new com-

* The doctor does not mean to affirm that electricity never occasions combustion, the contrary of which is well known, but that a combination produced by it is not always the same with combustion.

pound. Hence these compounds burn with amazing facility, not only when heated, but when triturated or struck smartly with a hammer. They have therefore received the name of *detonating* or *fulminating* bodies. Thus we have fulminating gold, fulminating silver, fulminating mercury, fulminating powder, &c.

9. Such are the properties of the combustibles, the supporters, and the products; and such the phenomena which they exhibit when made to act upon each other.

If we compare together the *supporters* and the *products*, we shall find that they resemble each other in many respects. Both of them contain oxigen as an essential constituent part; both are capable of converting combustibles into products; and several of both combine with combustibles and with additional doses of oxigen. But they differ from each other in their effects on combustibles. The former only produce combustion; whereas the products convert combustibles into products without combustion. Now, as the ultimate change produced upon combustibles by both these sets of bodies is the same, and as the substance which combines with the combustibles is in both cases the same, namely oxigen, we must conclude that this oxigen in the supporters contains something which the oxigen of the products wants, something which separates during the passage of the oxigen from the product to the combustible, and occasions the combustion, or emission of fire, which accompanies this passage. The oxigen of supporters then contains some ingredient which the oxigen of products wants. Many circumstances concur to render it probable that this ingredient is *caloric*.

The *combustibles* and the *products* also resemble each other. Both of them contain the same or a similar base; both frequently combine with combustibles, and likewise with oxigen; but they differ essentially in the phenomena which accompany their combination with oxigen. In the one case *fire is emitted*, in the other not. If we recollect that no substance but a combustible is capable of restoring combustibility to the base of a product, and that at its doing so it always loses its own combustibility;

and if we recollect farther, that the base of a product does not exhibit the phenomena of combustion even when it combines with oxigen, we cannot avoid concluding, that all combustibles contain an ingredient which they lose when converted into products and that this loss contributes to the fire which makes its appearance during the conversion. Many circumstances contribute to render it probable that this ingredient is *light.*

If we suppose that the oxigen of supporters contains caloric as an essential ingredient, and that light is a component part of all combustibles, the phenomena of combustion above enumerated, numerous and intricate as they are, admit of an easy and obvious explanation. The component parts of the oxigen of supporters are two; namely, 1. a base, 2. caloric: The component parts of combustibles are likewise two; namely, 1. a base, 2. light. During combustion the base of the oxigen combines with the base of the combustible, and forms the product; while at the same time the caloric of the oxigen combines with the light of the combustible, and the compound flies off in the form of fire. Thus combustion is a double decomposition; the oxigen and combustible divide themselves each into two portions, which combine in pairs; the one compound is the *product,* and the other the *fire,* which escapes.*

Hence the reason that the oxigen of products is unfit for combustion. It wants its caloric. Hence the reason that combustion does not take place when oxigen combines with products or with the base of supporters. These bodies contain no light. The caloric of the oxigen of course is not separated, and no fire appears. And this oxigen still retaining its caloric, is capable of producing combustion whenever a body is presented which contains light, and whose base has an affinity for oxigen. Hence also the reason why a combustible alone can restore combustibility to the base of a product. In all such cases a double decom-

* This doctrine has been taught many years by Dr. Crichton, and is amply elucidated by a series of ingenious experiments in his lectures on chemistry.

position takes place. The oxigen of the product combines with the base of the combustible, while the light of the combustible combines with the base of the product.

But the application of this theory to all the different phenomena described above, is so obvious, that it is needless to give any more examples. Let us rather inquire, with the author, into the evidences which can be brought forward in its support.

10. As caloric and light are always emitted during combustion, it follows that they must have previously existed in the combustible, the supporter, or in both.

That the oxigen of the supporters contains either one or both of these substances, follows incontrovertibly from a fact already mentioned, namely, that the oxigen of products will not support combustion, while that of supporters will. Hence the oxigen of supporters must contain something which the oxigen of the products wants, and this something must be caloric, or light, or both.

That the oxigen of some of the supporters at least contains caloric as an ingredient, has been proved, in a satisfactory manner, by the experiments of Crawford, Lavoisier, and La Place. Thus the temperature of hot blooded animals is maintained by the decomposition of *air*. Now if the oxigen of one supporter contains caloric, the same ingredient must exist in the oxigen of every supporter, because all of them are obviously in the same state. Hence we conclude that the oxigen of every supporter contains caloric as an essential ingredient.

The light emitted during combustion must either proceed from the combustible or the supporter. That it proceeds from the combustible must appear pretty obvious, if we recollect that the colour of the light emitted during combustion varies, and that this variation usually depends, not upon the supporter, but upon the combustible. Thus charcoal burns with a red flame, sulphur with a blue or violet, zinc with a greenish white, &c.

The formation of combustibles in plants obviously requires the presence and agency of light. The leaves of plants emit oxigen gas when exposed to the sun's rays, but never in the shade, or in the dark, (page 120).

Besides vegetation, we are acquainted with two other methods of *unburning* products, or of converting them into products and combustibles, by exposing them, in certain circumstances, to the agency of *fire* or of *electricity*. The oxides of lead, mercury, &c. when heated to redness, are decomposed, oxigen gas is emitted, and the pure metal remains behind, (page 187). In this case the necessary caloric and light must be furnished by the fire; a circumstance which explains why such reductions always require a red heat. When carbonic acid is made to pass repeatedly over red-hot charcoal, it combines with a portion of charcoal, and is converted into gazeous oxid of carbon. If this gas be a combustible oxid, the base of the carbonic acid and its oxigen must have been supplied with light and caloric from the fire; but if it be a *partial combustible*, it is merely a compound of carbonic acid and charcoal: which of the two it is, remains still to be ascertained.

Electricity decomposes water, and converts it into oxigen gas and hidrogen gas; it must therefore supply the heat and the light which these bodies lost when converted into a product.

These facts, together with the exact correspondence of the theory given above with the phenomena of combustion, render it so probable, that Dr. Thomson has ventured to propose it as an additional step towards a full explanation of the theory of combustion. Every additional experiment has served to confirm it more and more. It even throws light upon the curious experiments of the accension of metals with sulphur, (page 149) which succeed, as stated already, *in vacuo*, under mercury, in nitrogen gas, &c.

Dr. Thomson has noticed that the same emission of caloric and light, or of *fire*, takes place when melted sulphur is made to

combine with potash, or with lime, in a crucible or glass tube, and likewise when melted phosphorus is made to combine with lime heated to redness, (page 165). He supposes that in all probability barytes and strontia exhibit the same phenomenon when combined with melted sulphur or phosphorus; and perhaps some of the metals when combined with phosphorus.

The phenomena Dr. Thomson explains thus: The sulphur and phosphorus are in the melted state, and therefore contain caloric as an ingredient; the alcalies, earths and metals which produce the phenomenon in question, contain light as an essential ingredient. The sulphur or phosphorus combines with the base of the metal, earth or alcali; while at the same time the *caloric* to which the sulphur or phosphorus owed its fluidity, combines with the *light* of the metal, earth or alcali; and the compound flies off under the form of *fire*.

Thus the process is exactly the same with combustion, excepting as far as regards the product. The melted sulphur or phosphorus acts the part of the *supporter*, while the metal, earth or alcali occupies the place of the *combustible*. The first furnishes caloric, the second light, while the base of each combines together. Hence we see that the base of sulphurets and phosphurets resembles the base of products in being destitute of light, the formation of these bodies exhibiting the separation of fire like *combustion*, but the product differing from a product of combustion in being destitute of oxigen, Dr. Thomson distinguishes the process by the title of *semi-combustion*; indicating by the term, that it possesses one half of the characteristic marks of combustion, but is destitute of the other half.

The only part of this theory which requires proof is, that light is a component part of the earths and alcalies. But as potash and lime are the only bodies of that nature, which we are certain to be capable of exhibiting the phenomena of semi-combustion, the proofs must of necessity be confined to them. That *lime* contains light as a component part has been long known. Meyer

and Pelletier observed long ago, that when water is poured upon lime not only heat but light is emitted. Light is emitted also abundantly when sulphuric acid is poured upon magnesia or upon lime, potash, or soda, freed from the water of crystallization, (page 134). In all these cases a *semi-combustion* takes place. The water and the acid being solidified give out *caloric*, while the lime or potash gives out *light*.

That lime during its burning combines with light, and that light is a component part of lime is demonstrated by the following experiment, for which we are indebted to Scheele.

It has been mentioned already (page 131), that fluor spar (fluate of lime) has the property of phosphorescing strongly when heated, but the experiment does not succeed twice with the same specimen. After it has been once heated sufficiently, no subsequent heat will cause it to phosphorate. Now phosphorescence is merely the emission of light, light of course is a component part of fluor spar, and heat has the property of separating it. But the phosphorescing quality of the spar may be again recovered to it, or which is the same thing, the light which the spar had lost may be restored by the following process:

Decompose the fluate of lime by sulphuric acid, and preserve the fluoric acid separate, (page 344). Boil the sulphate of lime thus formed with a sufficient quantity of carbonate of soda; a double decomposition takes place; sulphate of soda remains in solution, and carbonate of lime precipitates. Ignite this precipitate in a crucible till it is reduced to lime, and combine it with the fluoric acid to which it was formerly united. The fluor spar thus regenerated phosphoresces as at first. Hence the lime during its ignition must have combined with light.

That potash contains light, may be proved in the same manner as the existence of that body in lime. Now as potash is deprived of its carbonic acid by lime, the Doctor supposes that the process must be a double decomposition; namely, that the base of the lime combines with carbonic acid, while its light combines with the potash.

These remarks on semi-combustion might easily be much enlarged upon. For it is obvious, that whenever a liquid combines with a solid containing light, and the product is a solid body, something analogous to semi-combustion must take place. Hence the reason why water increases the violence of combustion when thrown sparingly into a common fire, &c.

Such is the theory of Dr. Thomson, against which a few objections have been advanced by an anonymous writer, *(Nicholson's Journal, July*, 1802, *p.* 206.) but there is little doubt that these objections will soon be reconciled, when the ingenious investigations of Dr. Thomson have been the subject of further consideration.

END OF VOL. I.

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